Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

REYNOLDS LIBRARY

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 103.

B. T. GALLOWAY, *Chief of Bureau.*

DRY FARMING IN THE GREAT BASIN.

BY

CARL S. SCOFIELD,

Agriculturist in Charge of Western Agricultural
Extension Investigations.

Issued May 31, 1907.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The scientific and technical publications of the Bureau of Plant Industry, which was organized July 1, 1901, are issued in a single series of bulletins, a list of which follows.

Attention is directed to the fact that the publications in this series are not for general distribution. The Superintendent of Documents, Government Printing Office, Washington, D. C., is authorized by law to sell them at cost, and to him all applications for these bulletins should be made, accompanied by a postal money order for the required amount or by cash.

No. 1. Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.
2. Spermatogenesis and Fecundation of Zamia. 1901. Price, 20 cents.
3. Macaroni Wheats. 1901. Price, 20 cents.
4. Range Improvement in Arizona. 1902. Price, 10 cents.
5. Seeds and Plants Imported. Inventory No. 9. 1902. Price, 10 cents.
6. A List of American Varieties of Peppers. 1902. Price, 10 cents.
7. The Algerian Durum Wheats. 1902. Price, 15 cents.
8. A Collection of Fungi Prepared for Distribution. 1902. Price, 10 cents.
9. The North American Species of Spartina. 1902. Price, 10 cents.
10. Records of Seed Distribution, etc. 1902. Price, 10 cents.
11. Johnson Grass. 1902. Price, 10 cents.
12. Stock Ranges of Northwestern California. 1902. Price, 15 cents.
13. Range Improvement in Central Texas. 1902. Price, 10 cents.
14. Decay of Timber and Methods of Preventing It. 1902. Price, 55 cents.
15. Forage Conditions on the Border of the Great Basin. 1902. Price, 15 cents.
16. Germination of the Spores of Agaricus Campestris, etc. 1902. Price, 10 cents.
17. Some Diseases of the Cowpea. 1902. Price, 10 cents.
18. Observations on the Mosaic Disease of Tobacco. 1902. Price, 15 cents.
19. Kentucky Bluegrass Seed. 1902. Price, 10 cents.
20. Manufacture of Semolina and Macaroni. 1902. Price, 15 cents.
21. List of American Varieties of Vegetables. 1903. Price, 35 cents.
22. Injurious Effects of Premature Pollination. 1902. Price, 10 cents.
23. Berseem. 1902. Price, 10 cents.
24. Unfermented Grape Must. 1902. Price, 10 cents.
25. Miscellaneous Papers. 1903. Price, 15 cents.
26. Spanish Almonds. 1902. Price, 15 cents.
27. Letters on Agriculture in the West Indies, Spain, etc. 1902. Price, 15 cents.
28. The Mango in Porto Rico. 1903. Price, 15 cents.
29. The Effect of Black Rot on Turnips. 1903. Price, 15 cents.
30. Budding the Pecan. 1902. Price, 10 cents.
31. Cultivated Forage Crops of the Northwestern States. 1902. Price, 10 cents.
32. A Disease of the White Ash. 1903. Price, 10 cents.
33. North American Species of Leptochloa. 1903. Price, 15 cents.
34. Silkworm Food Plants. 1903. Price, 15 cents.
35. Recent Foreign Explorations. 1903. Price, 15 cents.
36. The "Bluing" of the Western Yellow Pine, etc. 1903. Price, 30 cents.
37. Formation of the Spores of the Sporangia of Rhizopus Nigricans and of Phycomyces Nitens. 1903. Price, 15 cents.
38. Forage Conditions in Eastern Washington, etc. 1903. Price, 15 cents.
39. The Propagation of the Easter Lily from Seed. 1903. Price, 10 cents.
40. Cold Storage, with Reference to the Pear and Peach. 1903. Price, 15 cents.
41. The Commercial Grading of Corn. 1903. Price, 10 cents.
42. Three New Plant Introductions from Japan. 1903. Price, 10 cents.
43. Japanese Bamboos. 1903. Price, 10 cents.
44. The Bitter Rot of Apples. 1903. Price, 15 cents.
45. Physiological Rôle of Mineral Nutrients in Plants. 1903. Price, 5 cents.
46. Propagation of Tropical Fruit Trees, etc. 1903. Price, 10 cents.
47. The Description of Wheat Varieties. 1903. Price, 10 cents.
48. The Apple in Cold Storage. 1903. Price, 15 cents.
49. Culture of the Central American Rubber Tree. 1903. Price, 25 cents.
50. Wild Rice: Its Uses and Propagation. 1903. Price, 10 cents.
51. Miscellaneous Papers. 1905. Price, 5 cents.
52. Wither-Tip and Other Diseases of Citrus Trees and Fruits Caused by Colletotrichum Gloeosporioides. 1904. Price, 15 cents.
53. The Date Palm. 1904. Price, 20 cents.

[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 103.

B. T. GALLOWAY, *Chief of Bureau.*

DRY FARMING IN THE GREAT BASIN.

BY

CARL S. SCOFIELD,

Agriculturist in Charge of Western Agricultural
Extension Investigations.

Issued May 31, 1907.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

BUREAU OF PLANT INDUSTRY.

Pathologist and Physiologist, and Chief of Bureau, Beverly T. Galloway.

Pathologist and Physiologist, and Assistant Chief of Bureau, Albert F. Woods.

Laboratory of Plant Pathology, Erwin F. Smith, Pathologist in Charge.

Investigations of Diseases of Fruits, Merton B. Waite, Pathologist in Charge.

Plant Life History Investigations, Walter T. Swingle, Physiologist in Charge.

Cotton and Tobacco Breeding Investigations, Archibald D. Shamel, Physiologist in Charge.

Corn Breeding Investigations, Charles P. Hartley, Physiologist in Charge.

Alkali and Drought-Resistant Plant Breeding Investigations, Thomas H. Kearney, Physiologist in Charge.

Soil Bacteriology and Water Purification Investigations, Karl F. Kellerman, Physiologist in Charge.

Bionomic Investigations of Tropical and Subtropical Plants, Orator F. Cook, Bionomist in Charge.

Drug and Poisonous Plant Investigations and Tea Culture Investigations, Rodney H. True, Physiologist in Charge.

Physical Laboratory, Lyman J. Briggs, Physicist in Charge.

Crop Technology Investigations, Nathan A. Cobb, Expert in Charge.

Taxonomic Investigations, Frederick V. Coville, Botanist in Charge.

Farm Management Investigations, William J. Spillman, Agriculturist in Charge.

Grain Investigations, Mark A. Carleton, Cerealist in Charge.

Arlington Experimental Farm, Lee C. Corbett, Horticulturist in Charge.

Sugar-Beet Investigations, Charles O. Townsend, Pathologist in Charge.

Western Agricultural Extension Investigations, Carl S. Scofield, Agriculturist in Charge.

Dry Land Agriculture Investigations, E. Channing Chilcott, Agriculturist in Charge.

Pomological Collections, Gustavus B. Brackett, Pomologist in Charge.

Field Investigations in Pomology, William A. Taylor and G. Harold Powell, Pomologists in Charge.

Experimental Gardens and Grounds, Edward M. Byrnes, Superintendent.

Vegetable Testing Gardens, W. W. Tracy, sr., Superintendent.

Seed and Plant Introduction, David Fairchild, Agricultural Explorer in Charge.

Forage Crop Investigations, Charles V. Piper, Agrostologist in Charge.

Seed Laboratory, Edgar Brown, Botanist in Charge.

Grain Standardization, John D. Shanahan, Expert in Charge.

Mississippi Valley Laboratory, St. Louis, Mo., Hermann von Schrenk, Expert in Charge.

Subtropical Laboratory and Garden, Miami, Fla., Ernst A. Bessey, Pathologist in Charge.

Plant Introduction Garden, Chico, Cal., August Mayer, Expert in Charge.

South Texas Garden, Brownsville, Tex., Edward C. Green, Pomologist in Charge.

Cotton Culture Farms, Seaman A. Knapp, Lake Charles, La., Special Agent in Charge.

Editor, J. E. Rockwell.
Chief Clerk, James E. Jones.

Withdrawn
FEB 7 '40

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture.
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 6, 1907.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 103 of the series of this Bureau, the accompanying manuscript, entitled " Dry Farming in the Great Basin," by C. S. Scofield, Agriculturist in Charge of Western Agricultural Extension Investigations.

Nearly one-third of the arable land of the United States is either arid or semiarid, and consequently can be used for agriculture only when irrigated or when devoted to such crops as are able to thrive with a limited supply of moisture or such as permit special tillage by which the scanty rainfall may be secured and held in the soil.

Notwithstanding the natural drawbacks of this great semiarid region, which occupies the larger part of the western United States, hardy pioneers have found within it many places where profitable farming is possible, and they have worked out tillage methods and found suitable crops for some sections that were believed a quarter of a century ago to be unfit for anything but stock ranges.

In the present paper Mr. Scofield describes the natural conditions and discusses the farming methods and the crops for one of the sections of this arid region where " dry farming " is now successfully carried on. Some of the more important factors that have made this development possible are shown to be a distribution of the rainfall which is favorable as to season, a clean summer fallow between crops to conserve the rainfall of two seasons where necessary to produce a crop, and the maintenance of soil fertility by good tillage, together with the continued addition of organic matter to the soil. It is shown, also, that while something has been done in the way of using drought-resisting crops, secured either through introductions from other countries or by plant breeding, much still remains to be done in this direction, and that further work along this line, together with still more knowledge as to the efficiency and cost of various tillage methods, promises to greatly extend the boundaries of profitable agriculture in the arid West.

Respectfully,
B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page.
Introduction 7
Location and general description of the region 9
Experiments in dry farming in the Great Basin 11
  Private experiments in dry farming 13
  The Utah arid experiment farms 14
Local conditions which affect dry farming 15
  Precipitation mainly in winter 16
  Annual variation in rainfall 18
  Influence of local topography on rainfall 20
Methods of interseason tillage 22
  Maintenance of a clean summer fallow 24
  The importance of soil texture 25
Crops and crop tillage 27
  Tillage for wheat 28
  Tillage for alfalfa 29
  Thin seeding essential to best results 30
The sustained productiveness of dry-farmed soils 31
  The heavy soils not leached 32
  The importance of organic matter in the soil 33
  Conditions favoring nitrification 33
  The fixation of nitrogen 34
  Organic matter lost by oxidation 35
Dry farming supplementary to irrigation 35
Making a home on the dry lands 36
Summary 38
Description of plates 40
Index 41

ILLUSTRATIONS.

PLATES.

Page.
PLATE I. Fig. 1.—General view of the San Juan County Arid Farm, Utah. Fig. 2.—Field of wheat in shock on land adjacent to the San Juan County Arid Farm 40
II. Fig. 1.—Field showing the type of summer fallow maintained in every other series on the San Juan County Arid Farm. Fig. 2.—The interior of an alfalfa plat on the San Juan County Arid Farm 40
III. Fig. 1.—A poor crop of wheat on the Sevier County Arid Farm, Utah. Fig. 2.—A crop of wheat grown without irrigation in the Cache Valley, Utah 40
IV. Fig. 1.—Harvesting wheat grown without irrigation, near Nephi, Utah. Fig. 2.—A hillside garden in a semiarid region, showing one of the settling ditches used to catch and hold the water which runs off the hill above 40

TEXT FIGURES.

FIG. 1. Map showing the location of the Great Basin 10
2. Sketch map of Utah, showing the irrigated areas according to the census of 1900 and the location of arid experiment farms 14
3. Diagrams showing the average monthly precipitation at some representative points in the semiarid West 18
4. Diagram showing the total annual precipitation at Logan, Utah, 1893–1906 19
5. Diagram showing the total annual precipitation at Tooele, Utah, 1897–1906 20
6. Diagram showing the total annual precipitation at Levan, Utah, 1890–1906 21
7. Diagram showing the total annual precipitation at Parowan, Utah, 1891–1906 22
8. Profile sketch showing the relative positions of Deseret, Fillmore, and Richfield, Utah 23

B. P. I.—266.

DRY FARMING IN THE GREAT BASIN.

INTRODUCTION.

During the past four or five years much interest has been manifested by the people of this country in the possibility of utilizing for agriculture some of the arable land in the western United States where the rainfall is insufficient for ordinary farming. There are several conditions that have contributed to this interest. American agriculture has enjoyed a large measure of prosperity during recent years and agricultural investment and farm-home development have received an unusual impetus. The choicest of the well-watered public lands have passed into private ownership and have greatly advanced in price.

Then, also, during the last two or three years there has been rather more than the normal amount of rainfall over the larger part of the arid region, and many people acquainted only with the present conditions firmly believe that the climate is gradually becoming more humid. This belief is probably without any foundation in fact, and it is surprising that it should exist, for the precipitation records of the whole country receive wide publicity; but since the idea is generally held and has been widely advertised it becomes important to emphasize the fact that there is no adequate basis for hoping that the climate of the arid West is undergoing any appreciable change as regards precipitation.

Within recent years, also, investigation and experimentation have been directed toward the solution of some of the complicated problems involved in the conservation of soil moisture in these arid regions. Actual additions to existing knowledge of the subject have been relatively few, but public attention has been directed to the work to such an extent that the idea prevails that much more is now possible in the way of utilizing a limited rainfall than was ever possible before. There is some foundation for such a conclusion, but nothing to warrant many of the exaggerated statements now current. The conquest of the arid West, to be successful and to be accomplished without large and costly failures, must be made slowly and by the careful application of definitely ascertained facts. The boundaries of existing settlements may be gradually extended, but any wholesale attempt to colonize large areas of this arid land with people accustomed to farming only in humid regions or not accustomed to farming at all is almost certain to result in disastrous failure.

The region just east of the Rocky Mountains has already been the scene of some large booms in arid lands. One of the first of these, which occurred from 1880 to 1885, was partly the result of a series of years of relatively high precipitation and partly the result of very extensive railroad building. A series of drier years following drove back many of the new settlers after they had lost all their possessions while waiting for a rainy season to come again. There have since been a number of smaller booms, which have affected different parts of the region at different times, as a result of temporary periods of increased rainfall or some other local cause. One of these, in the two or three years following 1890, began to assume large proportions when the financial crisis of 1893 and the severe drought of 1894 combined to drive back most of the new settlers. As each of these early waves of settlement receded, it left behind some few pioneers, who, by dint of harder work, by the use of better judgment in selecting land, or by turning to stock raising and using as range land the farms of their less persistent neighbors, succeeded in holding out through the dry years.

The region just west of the Rocky Mountains, particularly that portion of it lying within the State of Utah, was first settled by farmers who depended exclusively upon irrigation for crop production. The extensions of their settlements were naturally made along those streams from which the diversion of water for irrigation was possible. These first settlements were made about 1850, and for the next thirty years irrigation farming and stock raising on the open range constituted the only agriculture of the region.

In the decade of 1870–1880, some pioneer attempts were made to grow crops without irrigation in and around some of the valleys of the Great Basin. These attempts finally showed the way to the utilization of large tracts of fertile land for which no irrigation water could be had. The first efforts were relatively few and unimportant, but as the country became more thickly settled and new irrigation enterprises became scarce and expensive more attention was directed to the development of these nonirrigable lands.

This development was begun by growing crops to supplement those grown on the irrigated land. Almost no attempts were made at first to establish farms on the dry lands, so that the first failures, by which the methods of success were learned, were not so disastrous as they might have been had it been necessary to build homes and make other improvements independent of any irrigation opportunities. It is manifestly much easier to experiment in dry farming, to gamble on the weather as it were, if one has an irrigated farm to fall back upon in adverse seasons. Even where it is possible by the use of windmills or the development of springs or small streams to irrigate relatively small fields during a protracted drought, the settler is able to tide over times when without such a resource complete failure would be inevitable. When the utilization of the dry lands can proceed from well-established agricultural centers, such as irrigated sections, instead of having to start unsupported in the midst of the dry lands, the risk of disastrous failure is greatly reduced.

From the modest and tentative beginnings of a third of a century ago there has grown a well-established system of farming in some sections of the country west of the Rocky Mountains. There are in this great intermountain area three fairly well defined regions in which dry farming[a] is now practiced to a considerable extent. For convenience of designation, these regions may be named the Great Basin, the Columbia River Valley, and the interior valley of California. Each of these areas includes localities with widely differing conditions of soil, climate, and agriculture, and each, taken as a whole, differs from the others in important particulars, yet they have some important features in common not shared by the Great Plains region, which includes most of the arid lands east of the Rocky Mountains.

LOCATION AND GENERAL DESCRIPTION OF THE REGION.

The agricultural region referred to as the Great Basin area (fig. 1) occupies a portion of the great depression between the Rocky Mountains and the Sierra Nevada. To the north of the Great Basin lies the drainage basin of the Columbia River, while to the southward the drainage is collected by the Colorado River. The Great Basin proper is well defined topographically. It includes a large irregular body of land lying chiefly in the States of Utah, Nevada, Oregon, and California, of which the drainage finds no outlet to the ocean, but instead collects in various lakes and sinks, from which it evaporates.

---

[a] The term "dry farming" is a recent addition to agricultural literature, but since it meets a real need it will probably find a permanent place. There is some difference of opinion as to just what the expression means. It is ordinarily understood to mean farming in an arid or semiarid region without irrigation, but this is often confusing, since "arid" is at best a relative expression and irrigation is often used even in humid regions. All good farming involves at least some tillage of the soil, which accomplishes several purposes at once. The soil is aërated, weeds are killed, the tilth is improved, and moisture is conserved. Sometimes one and sometimes another of these objects is the chief aim, and sometimes all are important. In dry farming, however, the one object of paramount importance is the conservation of soil moisture, and all the tillage operations are directed to this end.

The Great Salt Lake of Utah and a large depression in Nevada, formerly occupied by Lake Lahontan, are the two most important drainage centers, but there are numerous smaller lakes and sinks quite independent of these. In addition to the agricultural land in the Great Basin proper there is a considerable area of arable land lying between the eastern side of the Great Basin and the Rocky Mountains. This constitutes the northern portion of the Colorado River drainage basin, but in view of the similarity of conditions prevailing over this region and the near-by Great Basin it seems proper to include both in a discussion of the agriculture of the section, and in the present paper the term "Great Basin area" is used to include not only the Great Basin proper, but also the region between it and the Rocky Mountains. By far the larger part of the arable land of the Great Basin area lies at an altitude of more than 4,200 feet above sea level. The topography is broken by numerous mountain ranges, so that the arable land is confined to the intervening valleys and wash plains. These wash plains often occur as high mesas, with a gently rolling topography except where they are cut by the courses of streams and recent erosions.

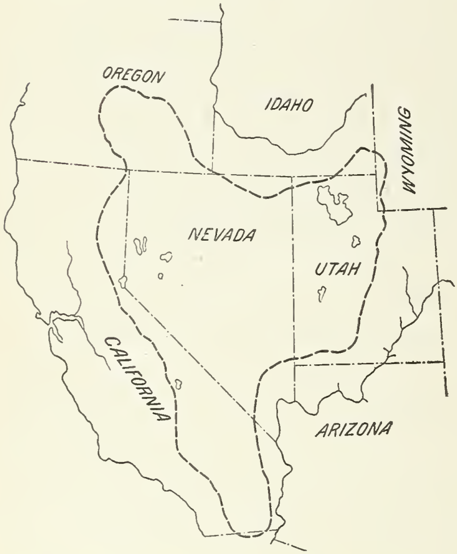

Fig. 1.—Map showing the location of the Great Basin.

The valleys of water courses are now all more or less developed by irrigation, while the higher mesas which can not be reached by gravity canals remain to be utilized without irrigation, if at all.

In the eastern part of the Great Basin area, where most of the dry farming is now done, the valleys and mesas are relatively small. One or two of them are 15 or 20 miles across, but many are only 1 to 4 miles across and of varying lengths. Often they lie between high timber-covered mountains that furnish perennial streams and a timber supply, as well as valuable range land. In other cases they are surrounded by relatively barren hills, which afford neither water nor timber and yield but little range.

In the northern and central portions of this area the higher and better-watered arable lands are covered with sagebrush (*Artemisia tridentata*) with its gray-green foliage. In the swales on the rolling mesas the dark green of the rabbit brush (Chrysothamnus) makes a pleasing contrast in the landscape. Among this shrubby growth various grasses naturally occur, Agropyron, Bouteloua, Stipa, and Bromus being the genera more commonly represented. In a few localities where conditions are favorable these grasses sometimes form a compact sod, but usually they occur in scattered tufts. On exposed situations and along the foothills, cedars of various species occur in scattering groups, usually marking rock outcrops or stony soil. In the lower valleys, particularly in the heavier and salty lands, the greasewood (*Sarcobatus vermiculatus*) replaces the sagebrush as the characteristic shrub, with intermingling grasses or sedges where enough moisture is available and with various saltbushes and saltworts, species of Atriplex and Dondia, where moisture is scant or alkali abundant.

In the southern part of the Great Basin area the sagebrush is replaced on the better lands by the creosote bush (*Covillea tridentata*), while the lower and more alkaline lands are occupied almost exclusively by the greasewood and the saltworts mentioned above. Along the water courses willows and cottonwoods are common, but aside from these the arable lands are treeless and easily brought under cultivation.

EXPERIMENTS IN DRY FARMING IN THE GREAT BASIN.

The first agricultural settlements in the Great Basin were made along the courses of streams, where water could be diverted for irrigation, and apparently for a long time no one thought farming without irrigation possible. As a consequence the early agriculture of the region was confined to relatively intensive irrigation farming and to ranging cattle and sheep on the higher lands. Irrigation farming included the production of most of the staple crops common to American agriculture, but with considerably more emphasis on wheat and alfalfa than on any other crops. According to the census of 1900 the State of Utah had somewhat more than 686,000 acres in specified crops. Of these, about 190,000 acres were devoted to wheat, about 270,000 acres to alfalfa, and nearly 115,000 acres to hay and other forage crops; in other words, nearly 85 per cent of the total acreage was devoted to these crops. Unlike the other irrigated sections of the West, the Great Basin area produces a considerable acreage of oats under irrigation. The area devoted to this crop in the Great Basin in 1899 was slightly more than 43,000 acres, while barley, which is the most important cereal besides wheat usually grown under irrigation in the West, was grown on less than 9,000 acres of Utah land. Corn is grown only to a limited extent, there being reported for 1899 only 11,000 acres, while 10,000 acres were devoted to potatoes and 5,000 acres to miscellaneous vegetables. Sugar beets and orchard fruits are important features among the agricultural industries of the area. The latter are both intensive crops, yielding high returns per acre. There were grown 7,500 acres of sugar beets and 16,000 acres of orchard fruits in 1899. These areas seem small for a whole State, but it should be remembered that only a relatively small part of the State has yet been utilized for agriculture. There remains much valuable land to be developed, both with and without irrigation. During the decade from 1889 to 1899 the irrigated acreage in Utah increased 138.8 per cent, or from 263,473 to 629,293 acres, and progress has been fully as rapid since, so that these figures may be increased safely by 50 per cent in estimating the present status of the agriculture of the area, and the indications are that the acreage devoted to dry farming has increased more rapidly even than the irrigated acreage.

In the State of Nevada, which lies almost wholly in the Great Basin, there is at present practically no farming without irrigation. The Twelfth Census reports for the State for 1899 a total in specified crops of 328,458 acres, of which 323,352 acres, or all but 5,000 acres, were irrigated. The difference, or unirrigated land, was nearly all in wild hay and probably irrigated naturally by overflow. There are without doubt numerous valleys in Nevada where dry farming is possible, but there is no evidence that any of these have yet been developed.

The portion of Oregon included in the Great Basin is as yet almost entirely without settlements, so that whatever resources it may have in the way of lands adapted to dry farming are still unknown.

Probably the most striking feature of the agricultural practice of Utah farmers is the lack of an intertilled annual crop to be grown in rotation with the cereals and hay. The discrepancy between the combined acreage of the three important intertilled crops (corn, potatoes, and sugar beets) as compared with the cereal and hay crops is very marked, there being only about 30,000 acres of this class of crops as compared with more than 550,000 acres of cereals, alfalfa, and tame grasses, or 1 acre of intertilled crops to 18 acres of the others. This discrepancy shows the acute need of finding varieties of such crops as corn and sorghum that can be used profitably in rotation with the cereals and forage crops, for it is difficult to secure the best results in general farming without the use, at least occasionally, of an intertilled crop in the rotation. This is particularly true in farming without irrigation, for crops that can not be cultivated during the growing season permit the waste by direct evaporation of a large amount of soil moisture, while with crops that can be intertilled there should be but little more moisture removed from the soil than is required by the crop itself.

PRIVATE EXPERIMENTS IN DRY FARMING.

It is not the present purpose to devote much space to an account of the beginning of dry farming in the Great Basin, but it may be said in passing that it was probably first systematically tried in the Cache Valley, near Logan, Utah, about 1870, or shortly before. The first attempts resulted in failure, but in a few years enough had been learned to justify a continuation and even a considerable extension of the practice. The idea seems to have spread slowly at first, and it has been only since 1885, or later, that it has reached any appreciable proportions, even in the Cache Valley, where water for irrigation was until recently ample for the needs of all the settlers.

Within the past two decades, and particularly during the last one, there has been an enormous increase in the acreage farmed without irrigation, until practically all the arable land in this valley is now utilized either with or without irrigation. The Twelfth Census, which gives the acreage of crops grown in 1899, reports a total of 58,658 acres irrigated in Cache County, which includes the Cache Valley and little else, while the total acreage in specified crops for the same year is nearly twice that area, so that for that year the acreage farmed without irrigation nearly equaled the irrigated acreage. The increase in acreage devoted to both kinds of farming has been rapid since 1899, and it is probable that at present there is more dry-farmed land in this valley than irrigated land. In the Bear River Valley and in the valley of the Malade River there is also a large area of dry-farmed land, which is rapidly extending northward and westward.

Along the eastern shore of Great Salt Lake, on the lower benches of the Wasatch Mountains, there are isolated patches of land farmed without irrigation, but in some of these cases, at least, there is probably subirrigation from seepage water. On the foothills of the west side of the Jordan River Valley, between Utah Lake and Great Salt Lake, and also in Utah County east of Utah Lake, there is now considerable dry farming on the higher lands. Much of this is of very recent development.

Directly south of Great Salt Lake, in Tooele County, Utah, there is a broad valley in which dry farming is now practiced to a considerable extent. In the eastern part of Juab County and south of Utah Lake, between Nephi and Levan, there has been a very rapid development of dry farming within the past six years.

The accompanying sketch map (fig. 2), which shows approximately the location of the irrigated land in the State of Utah, may serve to show also the location of the land farmed without irrigation, since it is only around the edges of the irrigated land that dry farming is at present carried on.

In the southwestern part of Utah, in Iron and Washington counties, dry farming is still in the experimental stage, but there are several valleys in these counties where success seems assured if proper methods are followed. In the southeastern part of the State, in San Juan County, there is a high plateau extending eastward into Colorado which probably contains a million acres of arable land adapted to dry farming. (See Pl. II, fig. 2.) This part of the State is difficult of access and is at present but little known.

In addition to the localities mentioned, there are many others in Utah and western Colorado where dry farming is, or may be, successfully carried on, at least supplementary to irrigation, if not independently.

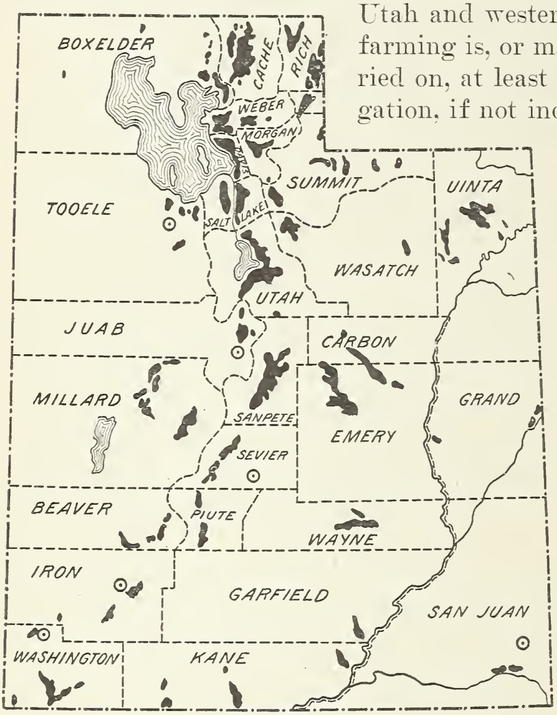

FIG. 2.—Sketch map of Utah, showing the irrigated areas according to the census of 1900 and the location of arid experiment farms.

THE UTAH ARID EXPERIMENT FARMS.

The importance of dry farming as a factor in the development of the State of Utah has been recognized by the people of that State to the extent that the legislature has made direct appropriations to establish and maintain experiment farms for working out scientifically the best methods of tillage and rotation and for testing crops and varieties to find those best suited to local conditions. Six such farms have been established in representative parts of the State; their approximate locations are shown on the sketch map, figure 2. These farms were provided for by an act of the Utah legislature approved March 6, 1903. Each of them contains 40 acres of land, is equipped with the necessary farm machinery, and is well fenced, but has no other improvements. The work is directed by the officers of the State Agricultural Experiment Station at Logan, Utah, while each farm is under the direct charge of a local superintendent. All the labor required, whether of men or teams, is employed by the day or by the hour from near-by farms. No live stock is kept on the farms.

On each of these farms systematic experiments have been planned with a view to working out some of the more important tillage and crop problems, both general and local. The land is laid off in long, narrow strips, which are subdivided crosswise into plats ranging from one-fifth to one-third of an acre in size. Except for a few experiments, these strips or series of plats are alternately put in crop and given a clean summer fallow. Plate I, figure 1, shows one of these experiment farms with the alternate series in crop and in fallow, while Plate II, figure 1, shows a portion of one of the fallow series and the way the surface mulch is maintained. The plans of the experiments and descriptions of the stations have been published by the Utah Agricultural Experiment Station, and the reports of results obtained are to be published from time to time, as required by the law under which they were established.[a]

These experiment stations, representing as they do a variety of conditions within the State, promise to be of great value in solving some of the problems of dry farming, particularly if they can be continued for a considerable length of time. From the fact that the same general plan of experiments is being followed on each of them, opportunity is offered to get a perspective on the results that would be quite impossible with only one or two such stations. In addition to this, these farms serve in a measure as demonstrations of what can be done and how best to do it in each of the sections where they are located. Such demonstrations are of the greatest value to a community, for the lessons of proper tillage methods for moisture conservation are hard to learn except by costly experiment or continued observation.

LOCAL CONDITIONS WHICH AFFECT DRY FARMING.

From the standpoint of dry farming the most important feature of climate is the precipitation; its amount, its distribution through the year, the variation in amount from year to year, and the way it falls—whether chiefly as snow, as frequent light showers, or as occasional torrential rains. These factors are, of course, all closely interrelated with others, such as temperature, atmospheric humidity, wind movement, and the character of the soil.

The success or failure of dry farming in the Great Basin is largely influenced by local conditions of climate and soil, so that a careful investigation of these conditions is well warranted, not only by anyone studying the subject as a whole, but also by anyone proposing to begin such farming in that region. Some of these conditions, such as the character and annual distribution of the rainfall, are much the same for the whole region, but other conditions, such as the actual amount of the rainfall, are largely influenced by the local topography and therefore vary greatly even within a limited area.

---

[a] "Arid Farming in Utah," Bul. 91, Expt. Sta., Utah, January, 1905, and "Memorandum of Plans for Arid Farm Investigations," Circulars No. 1 and 3, Expt. Sta., Utah, April, 1904, and April, 1905.

PRECIPITATION MAINLY IN WINTER.

In the Great Basin, as in nearly all of that part of the United States lying west of the Rocky Mountains, the larger part of the precipitation occurs during the winter rather than during the summer months. In this respect the climate differs from that of the great semiarid region east of the Rocky Mountains.

Contrary to the generally accepted opinion, there seems to be good reason for believing that more economical use of a limited rainfall is possible when the larger part of it takes place during the winter than when the rains are mostly confined to the summer months. This is particularly true when the rainfall is too light to produce a crop every year, so that summer fallowing or alternate-year cropping is necessary to conserve the scanty supply.

There are several reasons for this. When the rain comes during the cool weather a much smaller percentage of it is immediately evaporated than in warmer periods, so that more of it soaks into the ground. When rain falls on the hot, dry ground in midsummer it takes at least one-fourth of an inch to wet the surface and establish connection with the moist soil below, while on the heavier soils at least one-half inch is needed to penetrate the dry surface. After the rain has ceased a considerable quantity of water evaporates before the surface is dry enough to cultivate, if cultivation is possible, while with standing grain and similar crops the direct evaporation from the soil continues until all moisture within reach of the surface that has not been taken up by the plants meanwhile is lost into the air.

With a favorable soil—a soil with sufficient fine material to have a high water-holding capacity, yet with enough coarse material to permit easy penetration of rain water—the best use of a limited rainfall is possible when it occurs during the cooler months, either as snow or as slow rains of one-half an inch or more at a time, so as to give a maximum of penetration and a minimum of run-off and evaporation. This is, of course, not true for all climates nor for all soil types. Where the winters are long and severe, so that the ground is deeply frozen, winter precipitation would be largely wasted in surface run-off and by evaporation before the ground thawed out in the spring; while on shallow soils or soils with a relatively small amount of fine material, and consequently a low water-holding capacity, the rain that falls, except during the growing season, is largely lost by percolation to depths beyond the reach of plants.

It is well known that moisture may be lost very rapidly from a soil if the surface is not stirred soon after a rain. It is, therefore, only with intertilled crops that rain can be economically utilized during the hot growing season. For crops that can not be intertilled, such as wheat, oats, and barley, the greatest economy of soil moisture is possible if no rain falls after the crop is sown, or at least after the last surface tillage is given.[a] Where the soil is fairly heavy and deep it can hold available sufficient moisture to mature any ordinary crop, provided losses by direct evaporation are nearly or quite prevented.

The growing season of the ordinary crop plants is set within fairly definite limits. If moisture is not supplied at about the time it is needed, the plants either die outright or are injured beyond recovery. In farming with a limited rainfall there is therefor much less risk involved where it is possible to store in the soil during a whole year enough water to carry a crop to maturity than where it is necessary to depend on the chances of rains at just the proper time during the growing season. There is much less chance of a year-long drought than of a drought of two or three weeks during the summer when rain is badly needed for crops.

In figure 3 is shown the average monthly precipitation at four representative points in the eastern part of the Great Basin, while for purposes of comparison similar diagrams are shown of the precipitation at four representative points in the Great Plains area which lies on the eastern slope of the Rocky Mountains. The diagrams are arranged to show the average amount of precipitation in inches of water for each month in the year, and the months are arranged in the order of the calendar year, with January on the left and December on the right.

It may be seen at a glance that the seasonal distribution of the precipitation is strikingly different in the two regions represented. In the Great Basin the larger part of the rain falls in the autumn, winter, and early spring, while except at Parowan[b] the midsummer rainfall is almost negligible. On the other hand, the characteristic feature of the Great Plains climate is its relatively heavy summer rainfall and its dry winters.

---

[a] In the case of autumn-sown cereals it is not only practicable but decidedly advantageous to harrow the crop in the spring as late as it can be done without injuring the grain.

[b] Parowan is evidently far enough south to share somewhat in the torrential summer rains that often occur in Arizona and New Mexico.

ANNUAL VARIATION IN RAINFALL.

There are no rainfall records covering long periods of time for the places in the Great Basin where dry farming is now attracting the most attention. The earlier settlers were interested chiefly in irrigation farming and gave but little attention to rainfall. With few exceptions such records as are in existence have been made in cities or towns that were located with reference to irrigation or transportation facilities rather than in representative agricultural regions, and consequently the available records are of limited agricultural applition.

The following charts show the total annual precipitation at four places in Utah where dry farming is now carried on to some extent. In fact, the two towns Logan and Levan probably represent the best and most extensive development of dry farming in that region. Such records as these are valuable in proportion to their length, for when long continued they furnish a basis for interpreting present conditions without which wrong judgment would be almost certain.

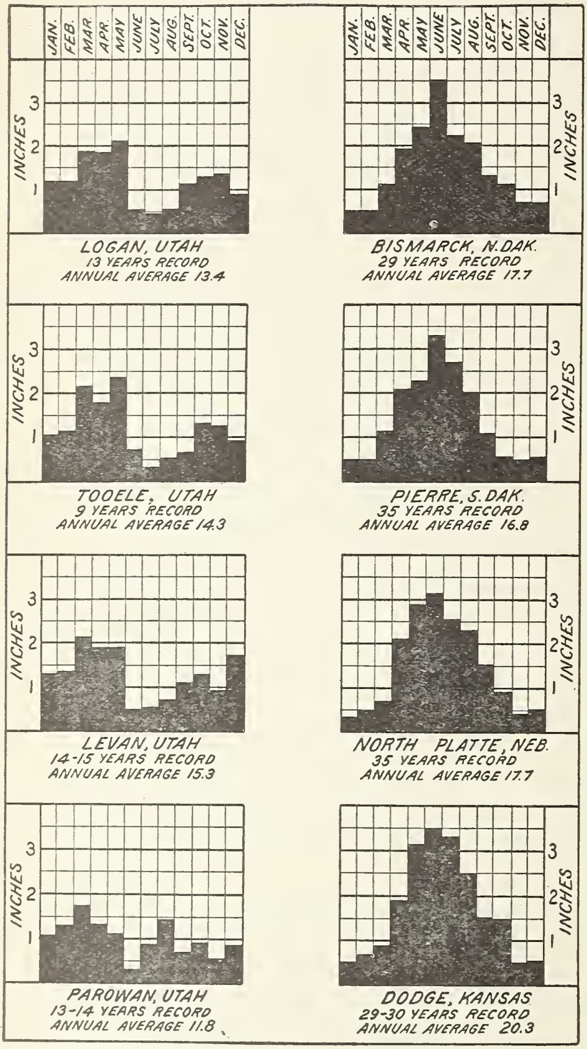

FIG. 3.—Diagrams showing the average monthly precipitation at some representative points in the semiarid West.

Logan, Utah, is situated near the northern boundary of the State, near the eastern side of the Cache valley, in which dry farming has been carried on for nearly a third of a century, and it is now probably the most important dry-farming section in the State. Except on the eastern side the valley is surrounded only by low hills, so that the rainfall is probably very evenly distributed over it. The record shown in the diagram (fig. 4) covers a period of fourteen years, from 1893 to 1906, inclusive, the annual average being 15 inches. It will be noted that for the period of record previous to 1906 the variation from the mean was slight, but in 1906 the amount of rain was nearly double what it was in 1905.

Tooele, Utah, is situated near the eastern edge of a broad valley directly south of Great Salt Lake. This valley, which lies at an altitude of about 4,500 feet, is one of the largest in the State in which dry farming is possible. The region around Tooele has not been used for dry farming until within the last three or four years. Records are available for the last ten years only. The annual average for that time is 15 inches, while the extremes range from about 10 inches to slightly over 20 inches. (See fig. 5.) It will be noted in this case, also, that the rainfall during 1906 was the greatest recorded, although the difference is not so marked as in the record for Logan.

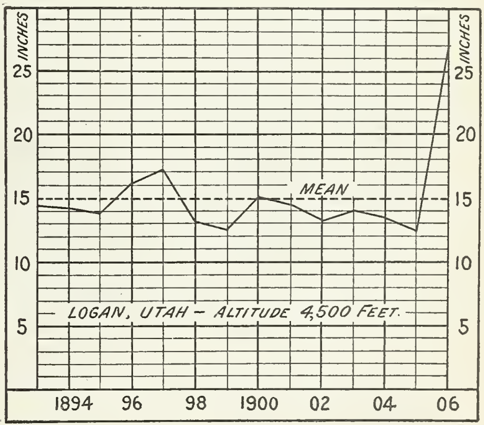

FIG. 4.—Diagram showing the total annual precipitation at Logan, Utah, 1893–1906.

Levan, Utah, is situated in a comparatively narrow valley in the central part of the State, a short distance south of Nephi. This valley is in one of the older settled sections of the State, and since 1900 it has been the scene of very rapid development of dry farming. This record also shows an unusually large rainfall during 1906, which was exceeded only in 1895. (See fig. 6.) It is clear from such a record as this that frequent crop failures can be avoided only by tillage methods by which a reserve of moisture is stored in the soil for the use of crops during the drier years.

Parowan, Utah, is situated near the southern part of the State in one of the smaller valleys east of the Escalante Desert. The annual average for the fourteen years recorded is 12.5 inches, while the extremes range from 21 inches as the highest to 7 inches as the lowest.

In this case, again, the unusual rainfall of 1906 is shown. It becomes apparent from a comparison of this (fig. 7) and the preceding diagrams that the rainfall of 1906 was much above the average in the Great Basin. The relatively large rainfall of 1906 has stimulated local interest in dry farming in a way that nothing else could do.

The wonderfully large crops obtained during the last season without irrigation, together with the recent unusual interest in dry farming, have combined to convince the local public that irrigation is rapidly becoming unnecessary in that region. In fact it is not generally realized how much more rain there was during the last year than usually falls. It is true that the present agitation in favor of dry farming in Utah was actively begun in 1902 and 1903, when the rainfall was rather below the average, so that while the greater rainfall of last year has probably encouraged unwarranted hopes as to what can be done without irrigation, yet the actual extension of farming has doubtless been much greater than it would have been without the increased rainfall. There can be no doubt that there will soon be drier years again, for the records of rainfall show no reason for believing that the climate is changing.

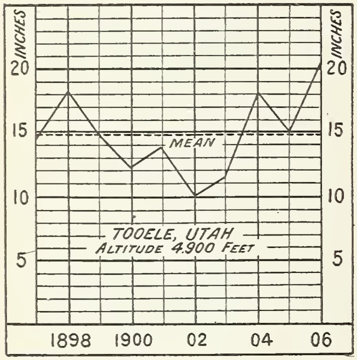

FIG. 5.—Diagram showing the total annual precipitation at Tooele, Utah, 1897–1906.

INFLUENCE OF LOCAL TOPOGRAPHY ON RAINFALL.

The air currents that bring rain into the Great Basin come mainly from the west, saturated with moisture from the Pacific Ocean. A large part of this water in the lower atmosphere is precipitated as this air passes over the high Sierra Nevada range, but enough moisture is soon recovered either from the upper air or from the earth for each of the successive mountain ranges in the Great Basin to receive its share of rain, the amount in each case increasing with the height of the ranges and their distance apart. Thus, just as the western part of the Great Basin is more arid than the eastern part, so the western side of each valley in the Great Basin is drier than the eastern side; or, conversely, the western slope and foothills of a mountain range receive more rainfall than the eastern slope, the difference depending somewhat upon the height of the range. (See fig. 8.)

The following table illustrates this phenomenon. The town of Deseret lies well out in a broad valley which is much too dry for any farming except with irrigation. About 30 miles southeast of Deseret is the town of Fillmore, which lies close to the western slope of a mountain range, the crest of which is 10,000 feet above sea level. In the first part of the table is shown the total annual precipitation at Deseret and Fillmore for all the years for which there are records, and also the difference in favor of Fillmore due to the effect of the mountains.

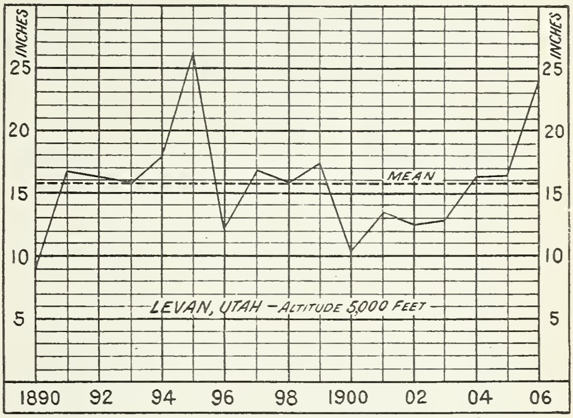

FIG. 6.—Diagram showing the total annual precipitation at Levan, Utah, 1890–1906.

In the second part of the table Fillmore is compared with Richfield, which is only 16 miles away, but on the opposite side of the mountain range. Here also all the available records for both places are given. In this case the difference is even greater than is shown in the first case. Such facts show plainly that it is useless to estimate the probable rainfall at any place in this region where records have not been kept unless the topography is well known and direct comparison is possible with a similar location where the facts are known.

TABLE I.—*Differences in total annual precipitation between points in Utah located near each other, arranged to show the influence of topography.*

Year.	Deseret and Fillmore.			Fillmore and Richfield.		
	Deseret (altitude, 4,600 feet).	Fillmore (altitude, 5,700 feet).	Difference in favor of Fillmore.	Fillmore (altitude, 5,700 feet).	Richfield (altitude, 5,308 feet).	Difference in favor of Fillmore.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1893	7.6	15.6	8.0	....	....	....
1894	8.0	13.4	5.4	....	....	....
1898	....	....	....	14.6	4.5	10.1
1899	....	....	....	14.5	8.3	6.2
1900	5.4	9.3	3.9	9.3	1.8	7.5
1901	9.0	12.9	3.9	....	....	....
1902	4.8	11.9	7.1	11.9	6.6	5.3
1903	7.0	12.0	5.0	....	....	....
1904	7.1	12.1	5.0	12.1	5.2	6.9
1905	9.7	16.1	6.4	....	....	....
1906[a]	10.5	20.0	9.5	20.0	6.6	13.4
Average	7.7	13.8	6.1	13.7	5.5	8.2

[a] July records missing.

METHODS OF INTERSEASON TILLAGE.

The methods of farming now in use on the dry lands of the Great Basin area are largely the results of private experiments, and consequently they possess some local peculiarities. It should be kept in mind that there are some unusual features of climate and soil in this region, such as the relatively light summer rainfall and a deep heavy soil that holds large quantities of water.

Deep plowing, frequent cultivation, and alternate-year cropping have been used in retaining soil moisture. Wheat sown in the autumn has been the chief crop grown on the dry lands, and for this reason the land is plowed in the late summer as soon as possible after the crop has been removed. The land is left in the rough furrow all winter, and as soon as the winter rains have either soaked in or dried off, surface cultivation is begun. This cultivation is done chiefly with a disk harrow, though other implements are also used. Sometimes a shallow summer plowing is given to kill and turn under any weeds that have escaped the lighter cultivation. In the late summer the spike-toothed harrow and other smoothing implements are used to prepare a fine seed bed, and the next crop is sown in September or early in October. Since the winter rains compact the soil and get it into such a condition that the direct loss of water would be easy, it is often found desirable to lightly harrow the wheat crop in the early spring, for after it starts to grow nothing more can be done toward preventing the loss of water until after harvest. Since wheat growing involves only the simpler farm operations, which may be performed on a large scale, there have been special inducements to use large machinery and to economize the use of men.

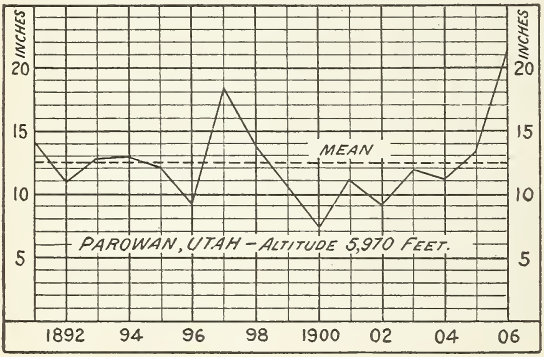

FIG. 7.—Diagram showing the total annual precipitation at Parowan, Utah, 1891-1906.

Large gang plows and large harrows are in common use, and the grain header is used almost exclusively in harvesting the crop. In a few cases steam is used as motive power for plowing, and apparently with success. Where used it is always with a traction engine, which draws the plows behind it instead of working with a cable and operating from both sides of the field.

No reliable data are at hand for estimating the relative cost of using steam and animals for plowing. The steam outfit requires a large initial investment, and can hardly compete with animals except where there is so much land under cultivation that it can be used a large part of the time.

Aside from the ordinary moldboard plow, the disk plow is extensively used in dry farming in Utah. The disk plow can be employed in plowing land when it is dry and hard, which is highly important, and it also pulverizes the furrow slice when the land is dry rather better than the moldboard plow. The disk plow can also be used in large gangs, and thus works very well behind a traction engine. For summer fallow plowing a light disk plow in gangs is very popular. Such a plow is about half way between an ordinary disk plow and a disk harrow. It cuts about 4 or 5 inches deep and turns the furrow sufficiently to cover any weeds or trash.

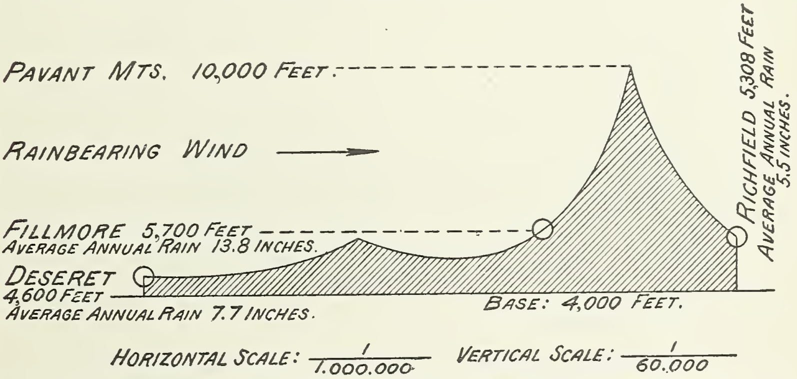

FIG. 8.—Profile sketch showing the relative positions of Deseret, Fillmore, and Richfield, Utah.

Where subsoiling is practiced, the use of a subsoiling attachment in a gang plow is found to be not only practicable but preferable. One very satisfactory disk gang plow that is made for use with five or six horses has two large disks for general use, but when subsoiling is to be done the front disk can be removed and a subsoiler attached in its place. This position of the subsoiler has several advantages. It leaves a smooth-bottomed furrow for the furrow horses to walk in and it also immediately covers the subsoil that is loosened by the subsoil plow, thus preventing a considerable loss of moisture that might result from leaving this loosened subsoil exposed to the air until the next round of the plow. There is some question as to whether subsoil plowing is worth what it costs, and many farmers are of the opinion that deep plowing without subsoiling is the better practice.

The ordinary disk harrow is, of course, in very general use, not only for pulverizing the soil in preparing a seed bed but also to maintain the clean fallow which is so essential to success in this type of farming

The spike-toothed harrow is also used almost universally, not only as a supplement to the disk harrow but also to kill weeds and break the surface crust after rains.

In addition to the smoothing harrow for finely pulverizing the surface soil, some farmers have used with advantage a plank drag, usually of home construction, made of three or four planks fastened together rigidly, one behind another, and with the edges overlapping like the weatherboards of a house. This implement crushes the hard lumps and tends to level the land at the same time. For still further smoothing and pulverizing the seed bed a brush harrow is sometimes used. This, too, is of home construction. It is made of brush rigidly fastened to a plank or log in such a way that the loose ends of the brush bear on the soil, acting much like a coarse broom. This brush harrow, when used after a plank drag, leaves the surface soil in excellent tilth.

For preparing new land for the plow, some sort of implement is often needed to remove the sagebrush. For this purpose a common railroad rail is often used, with a team hitched to each end and the rail dragged sideways across the land, breaking down the brush. This may be followed by a heavy rake, which gathers up the loosened brush into piles or windrows for burning. Several other implements have been devised for removing sagebrush, among them a heavy form of revolving hayrake, which breaks down and partly collects the brush in one operation.

MAINTENANCE OF A CLEAN SUMMER FALLOW.

The term "summer fallow" is used with different meanings in various parts of the country. In the Great Plains area, especially in the northern part, it is applied to the practice of letting the land lie idle and permitting the growth of weeds during the spring months, so that a plowing in June will not only kill these weeds but by turning them under add some much-needed humus to the soil. This June plowing also brings to the surface more weed seeds, which soon germinate and may be destroyed subsequently either by surface tillage or by fall plowing. The chief object of the summer fallow as used in the Great Plains area is rather to free the land from weeds than to conserve the moisture. In other sections of the country the term "fallow" is applied to the practice of leaving the land entirely undisturbed either for the whole or a part of the year. In the Great Basin, however, the summer fallow is used chiefly for moisture conservation.

As has been pointed out, the bulk of the precipitation of this region comes in the autumn, winter, and spring months, the summer months being almost free from rain. It is therefore possible to establish early in the season a very effective dust mulch on the surface of the soil, which is not likely to be disturbed by summer rains and which requires only enough cultivation to keep weeds from growing. (See Pl. II, fig. 1.) The maintenance of this surface mulch is an expensive operation even under these conditions, for weed seeds germinate readily in the moist soil below the surface, push up through the dry mulch, and unless quickly killed dissipate large quantities of valuable soil moisture. It is quite as important to keep weeds from developing to any considerable size as it is to maintain a surface mulch that will check direct evaporation. If these weeds are killed at short intervals by light surface cultivation they use but little water, and it is also much cheaper to destroy them when small than after they have grown to considerable size.

It must always be taken into account that the surface soil mulch, which is so necessary to moisture conservation, is possible only where the soil is sufficiently heavy not to be blown away by summer winds. These summer winds, which in some regions are almost continuous and sometimes of high velocity, often make a clean summer fallow altogether impracticable. It is also extremely doubtful if the requisite summer fallowing is practicable on very light soils, for even the milder summer winds would do serious damage where such a soil in a fine state of tilth is exposed.

THE IMPORTANCE OF SOIL TEXTURE.

The water-holding capacity of a soil depends largely upon its physical texture and is also influenced to some extent by the amount of organic matter present. For instance, a heavy clay soil containing a large amount of humus might hold 30 per cent of water and still be in workable condition, while sandy soil having 10 per cent of water might seem very wet. It is therefore obvious that where success in dry farming depends upon the storage in the soil within the reach of plants of enough water to carry a crop to maturity, the water-holding capacity of the soil becomes a matter of the first importance.

Table II.—*Increased moisture occasioned by 1 inch of rain distributed through various depths of soil, weighing 85 pounds per cubic foot.*

Depth of distribution.	Proportion of moisture.	Depth of distribution.	Proportion of moisture.
Inches.	*Per cent.*	*Inches.*	*Per cent.*
1	75	24	3.1
3	25	36	2
6	12.5	48	1.5
12	6.2	60	1.2

A cubic foot of heavy loam soil perfectly dry is estimated to weigh 85 pounds. A cubic foot of water weighs about 62½ pounds.

The water required to cover 1 square foot to the depth of 1 inch weighs about 5⅕ pounds, while an acre-inch of water weighs about 113 tons. One per cent of moisture per cubic foot of soil is equivalent to 0.84 pound of water, while 1 per cent per acre-foot of soil equals about 18 tons of water.

The preceding table shows the relation between rainfall and soil moisture as stated in percentages. These figures are useful in computing the potential effect of rains of various amounts, assuming that all of the rain enters the soil.

Estimating that a wheat crop, for instance, can use moisture 5 feet deep in the soil, it will be seen that a sandy soil would be able to hold available only about 540 tons of water per acre, while a heavy loam would hold available about 1,350 tons per acre, or a difference of more than 800 tons of water per acre in favor of the heavy soil. These figures show the importance of selecting only the heavier soils for dry farming where the storage of water from one season to another is necessary.

Under their virgin conditions the heavier and better soils of a semiarid region are rarely wet to a depth of more than 3 or 4 feet—often 2 feet or less. With the surface soil undisturbed so that this moisture can move upward and dissipate by direct evaporation, and with the natural vegetation using large quantities, it is only a short time after the rains cease before all the available water is lost from the soil. If this same land is broken by the plow to a depth of 5 or 6 inches, more of the rain water or melting snow soaks into it and penetrates far below the limit of virgin conditions. If, in addition to the first plowing, the surface soil is stirred frequently, a surface mulch is formed which is nearly as effectual in checking direct evaporation as a coat of oil on the surface of water. The moisture thus held in the soil continues downward, wetting soil that in some cases has not been wet for centuries. Since the total annual rainfall in many dry-farming regions is less than 15 inches, of which but little more than half can be secured and held even under favorable conditions, there is ample storage capacity in deep and heavy soils for all the normal rainfall of two years.

In short, the soil of a semiarid region may be regarded as a reservoir which under natural conditions is shallow, with a surface difficult to penetrate and favoring the quick loss of water by evaporation. Under proper methods of tillage the reservoir may be greatly deepened and provided with a cover that will effectually prevent evaporation, so that its supply may be held for the use of crop plants. It is the aim of interseason tillage to accomplish this result. With crops that do not permit intertillage during the growing season the importance of interseason tillage becomes very great, while the extensive use of intertilled crops lessens the need of it materially.

CROPS AND CROP TILLAGE.

Wheat and alfalfa are practically the only crops grown without irrigation in the Great Basin and, of the two, wheat is by far the more extensively grown. Other cereals, such as oats, barley, and rye, are grown in an experimental way, while such intertilled crops as corn, sorghum, potatoes, and field peas are also being tested to a limited extent.

There are several varieties of wheat in common use both on the dry lands and under irrigation. In fact, there has been but little attempt to develop strains or varieties especially for the dry lands. With a few exceptions, the wheats grown are fall-sown varieties of bread wheat (*Triticum aestivum*). They are nearly all light colored and belong to the class known commercially as "soft wheats." The more popular varieties are known locally under the names of Lofthouse, Kofoid, and Gold Coin.

On the State experiment farms a number of varieties of durum wheat (*Triticum durum*) have been under experiment, together with some of the spring wheats of the type grown in the upper Mississippi valley, such as Fife and Bluestem, and also some varieties of the hard, red winter wheats, such as are commonly grown in Kansas and Nebraska. These varieties are all regarded as still in the experimental stage, and they have not yet found their way into general use among farmers.

Alfalfa is the standard forage crop of the Great Basin area, as it is of the entire western United States. Among the people of Utah it is known universally as "lucern," the name under which it was first brought into the Eastern States, and which is derived from the common European name for the plant. This name was probably carried westward to Utah by the early pioneers, who never accepted the Californian name "alfalfa," which has been derived through the Spanish from an Arabic word signifying "the best fodder."

Alfalfa was first grown in the Great Basin only under irrigation, but recently it has been tested rather extensively on the dry lands. Apparently there has been no very serious effort made to secure varieties especially adapted to these dry lands, but instead seed from the irrigated land is harvested and put on the market, together with any seed that may be grown on land without irrigation.

The indications are that valuable drought-resistant varieties of alfalfa could be developed in a very short time if proper attention were given to selecting seed from individual plants or even from some whole fields that appeared to thrive well on a limited supply of moisture. It is true that a large proportion of the alfalfa seed now produced in this region receives very little, if any, irrigation, since a larger seed crop results when the plants are kept rather drier than is required for the best growth of forage. There needs to be a way devised by which it will be practicable to find recognition in the market for seed of alfalfa that is particularly drought resistant, as distinguished from seed of alfalfa that yields well only under liberal irrigation. If such recognition could be had, there would be an incentive for saving seed from the more drought-resistant plants or fields.

There are practically no grass crops grown on the cultivated dry lands of the Great Basin except in an experimental way. The experiment farms referred to are carrying on extensive trials with a number of promising grasses, including species of Bromus, Agropyron, Lolium, and Elymus. There are some indigenous species, particularly of Agropyron and Elymus, that are giving some promise under cultivation.

There is some doubt as to whether any of these grass crops will ever occupy an important position in dry farming, since they are nearly all shallow rooted and can therefore reach but a small part of the available soil moisture when it is really needed; and, furthermore, they are not well adapted to growing with intertillage or surface cultivation of any kind, whereas such cultivation is decidedly essential for crop production on these western dry lands.

TILLAGE FOR WHEAT.

On the dry lands of the Great Basin it is a common practice to grow wheat after wheat on the same land, sometimes continuously year after year and sometimes with alternate fallow years or with only an occasional fallow year, depending somewhat upon the moistrue condition of the soil. The ideal method of wheat farming and the one that appears to be the most profitable, all things considered, is the method of growing a crop every alternate year, with a year of clean summer fallow intervening. In this case the land is plowed deep, about 7 or 8 inches, very soon after harvest, or, if owing to a press of other work it is not possible to plow at once, the stubble is disked as soon as the grain is cut. The grain is usually harvested with a header, so that there is always a large amount of straw to plow under. During the following summer clean cultivation is given the land and wheat is sown again the following autumn.

If, as is often the case, the wheat is overripe when harvested, a considerable quantity shells out of the heads and falls to the ground, so that if the autumn rains come early and this wheat starts to grow there is always a strong temptation to leave the land unplowed. Not infrequently this volunteer wheat does very well and yields a good crop. (See Pl. III, fig. 1.) There are also cases where this first volunteer crop is allowed to reseed itself, but the resulting crop rarely amounts to much, owing to the irregularities of the stand and to the growth of weeds that quickly establish themselves under such conditions. In the long run, it is doubtful whether it ever pays to grow three or even two crops of wheat in succession without plowing the land between crops, for such practice not only wastes valuable soil moisture, but allows the land to become very weedy. (See Pl. III, fig. 1.)

TILLAGE FOR ALFALFA.

The young alfalfa plant is as tender and delicate as the well-established plant is strong and hardy, so that while it is necessary to have the land in excellent tilth and all other conditions favorable for starting this crop, a well-established field may be harrowed and disked, and sometimes even plowed, without destroying or even injuring the plants. In fact, surface cultivation when the plants are nearly or quite dormant, as in the early spring, seems to actually improve the stand and invigorate the growth.

The best results with alfalfa on the dry lands of the Great Basin are secured by early spring sowing with a drill on land that has been previously put in excellent condition of tilth. The seed is usually sown without a nurse crop, and the land should be as free from weeds as possible, for when the alfalfa plants are young they may be easily injured by weeds. During the first summer the new alfalfa field gets no attention except possibly a clipping with a mower set high to cut any rank weeds that may have started and to cut back the taller alfalfa plants. The plants cut down are usually left on the ground to form a mulch. The second summer the alfalfa field is in full bearing and may be cut once for a hay crop, and, if conditions are favorable, enough second growth will be made to give a light second crop.

When seed production is the aim of alfalfa growing, a light hay crop is usually cut very early, before the plants are in bloom, and the second crop is then the larger and sets seed freely. With alfalfa seed at its present price, seed production on the dry lands is much more profitable than the hay crop unless hay is very scarce and high priced.

After the second year a field may be disked and harrowed with impunity without injuring the plants, so that it is quite possible to materially aid in the conservation of soil moisture in alfalfa fields even if the ground is thickly covered with plants. On the dry lands of North Africa it has been found profitable to sow alfalfa in rows and cultivate it from time to time, and even to grow a wheat crop in alternate years without injuring the alfalfa, which would yield fair crops of hay during the fallow years.[a] It is reasonable to believe that similar results might follow attempts to grow alfalfa as an intertilled crop, either with or without wheat in alternate years, in the Great Basin, where conditions are in many respects similar to those in the higher lands of North Africa in the vicinity of Setif, where this method of growing alfalfa is in common practice. The quick response of alfalfa to cultivation is shown in Plate II, figure 2, which is reproduced from a photograph taken in the interior of a dry-land alfalfa field some weeks after the first crop of the season had been cut. The plants along the edge of the field next to the surface-tilled land had made a good second growth, while the plants in the interior of the field, where the available moisture had been exhausted by the first crop, had made practically no second growth.

There seems good reason for believing that sowing alfalfa in rows far enough apart to permit intertillage would be a profitable method on the dry lands, even for forage production, while for seed production it would almost certainly be more profitable. It is well known that isolated alfalfa when allowed to mature on these dry lands produces relatively large quantities of seed. This is probably due, in part, to a better illumination on all sides of the plant, resulting in a larger number of flowers; in part to the drier air surrounding these flowers during the pollinating period, which appears to have some bearing in seed production, and in part to the greater ease of access for insects of various kinds that promote pollination. It is certainly true that the partial isolation of the plants secured by row planting results in greatly increased yields of seed per plant, and there is strong probability that the yields per acre would be larger, so that experiments to determine this point would be well justified.

There is a strong tendency in the Great Basin, as elsewhere in the western United States, to let alfalfa grow in a field as long as it will, which is usually much longer than it is yielding its best returns. In other words, it is not used as a rotation crop, in the ordinary sense of the word. The beneficial effect of alfalfa upon the crop that follows it is generally recognized, but a well-established alfalfa sod is hard to subdue for the following crop, while alfalfa seed is expensive, and it is not easy to get a good, even start on a new field. The temptation is very strong, therefore, to leave alfalfa fields undisturbed, even though the increased yields of succeeding crops are much desired.

THIN SEEDING ESSENTIAL TO BEST RESULTS.

Under ordinary conditions in a humid region or with irrigation, farmers sow about 5 pecks of wheat or 75 pounds per acre, and from 15 to 20 pounds of alfalfa seed per acre. On the dry lands of the

---

[a] Bul. 72, Part I, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Great Basin, however, experience has shown that much better crops of wheat result when only 3 pecks of wheat or 45 pounds per acre are sown, while with alfalfa about 8 pounds of seed per acre gives the best results. Some farmers even sow 35 pounds of wheat per acre without apparently decreasing the yield, and careful experiments have shown that even less than 8 pounds of alfalfa seed per acre will give a good crop if evenly distributed, but uniform distribution is difficult with much less than 8 pounds of seed per acre. The beneficial effects of thin seeding are very striking, particularly in the drier years, when a seeding of 75 pounds of wheat results in crop failure, while a seeding of 35 pounds gives a good crop. This apparent anomaly is due to the fact that the heavier seeding results in so large and sudden a demand for soil moisture that the supply within reach is exhausted while the plants are still in the active growing condition and before the seed is formed, while with thin seeding the same amount of soil moisture is sufficient for the plants produced. Both wheat and alfalfa are able to throw out numerous branches from the central stem, so that when moisture conditions are favorable the number of stems actually produced may be nearly as great from thin seeding as from thick seeding.

THE SUSTAINED PRODUCTIVENESS OF DRY-FARMED SOILS.

In a system of farming where wheat is grown continuously, that is, not in rotation with other crops, such as is the case on the dry lands of the Great Basin, the question of maintaining the soil fertility is a natural and important one. It is ordinarily assumed that the continuous production of any one crop, and particularly such a crop as wheat, must rapidly reduce the fertility of the soil. It would seem, however, that with the tillage system for wheat, previously described, by which a clean summer fallow is given every second or third year and a large amount of straw is plowed under after each crop, the reduction of fertility is by no means so rapid as it is in some other regions and under some other conditions.

As a matter of fact, there are fields in some of the older settled valleys in the Great Basin that have been producing wheat every other year for a third of a century without showing any signs of depleted fertility. (See Pl. III, fig. 2.) While actual comparison is of course impossible, there are reasons for believing that some of these fields are capable of producing better crops now than when first plowed. If this be true, it is important to discover the causes involved and to determine whether this tillage method, if it be found a contributing cause, is capable of wider application with a hope of similar results. It must be kept in mind that in the practice followed on these dry lands, where the grain is headed rather than cut with the binder and where a large amount of straw is plowed under and incorporated with the soil, there is probably no reduction of the humus content; in fact, there might even be an increase of the humus under this practice, for the soils in their native condition bear but scanty vegetation, which probably adds organic matter to the soil very slowly.

With this large amount of wheat straw plowed under in the autumn and allowed to lie over the next winter, followed by continued surface tillage, conditions appear to be very favorable to the growth of any bacteria that might aid the conversion of this straw into available plant food. In fact, the conditions under which this surface mulch is maintained seem to be particularly favorable for the activities of nitrifying and other soil-enriching bacteria. It is well known that there are bacteria that under favorable conditions work on the complex proteids in the organic matter of the soil and change them into available plant food in the form of nitrates. In addition to these so-called nitrifying organisms, there are known to be other forms of bacteria that while living chiefly on the decaying nonnitrogenous organic matter of the soil are able to utilize and fix atmospheric nitrogen in much the same way as do those bacteria that live and develop nodules on the roots of some leguminous plants.

THE HEAVY SOILS NOT LEACHED.

The heavier soils such as have been found best suited to dry farming in the Great Basin have such a high water-holding capacity that with the ordinary light rainfall of the region there is no cumulative downward movement of water through them. In other words, the rain water that enters these soils is held by capillary force against the force of gravity, and instead of moving downward to join an underground water table, it is returned to the air either by direct evaporation from the soil surface or by transpiration processes through plants. This is, of course, not true for any but the deeper and heavier soils. Soils that occur as thin layers over impervious material, or those with so coarse a texture as to have a very low water-holding capacity, can not act as effective storage reservoirs. This fact again indicates the desirability of heavy soils for dry farming.

The importance of the fact that some of these dry-farmed soils are not leached by the rain water becomes apparent when it is realized that the soluble salts that result from the ordinary processes of soil weathering and from the activity of various organisms are not washed out of the soil, but remain to be used by plants. The proverbial richness of so-called arid soils, as well as the occurrence of alkali in soils of dry regions, is due to the fact that such soils are not leached by the rain.

THE IMPORTANCE OF ORGANIC MATTER IN THE SOIL.

A continued supply of organic matter in the soil appears to be absolutely essential to successful crop production. It is one of the most important sources of the various forms of nitrogen available to crop plants, and nitrogen in some combined and available form is of course absolutely necessary to plant growth.

Undecayed organic matter is not only useless to plants, but it is also likely to have an injurious mechanical effect upon the soil, at least in a dry region, by keeping it loose and open, thus making moisture conservation difficult. The processes of decay that take place in the organic matter in the soil are varied and complicated. Some of them result in additions to the supply of soluble salts used by plants, while others lead to the complete loss of the constituent substances through their reduction to gaseous forms and diffusion into the air, as in oxidation and denitrification. It therefore becomes important to consider something more in a tillage method than merely adding raw organic matter to the soil. This must be followed by providing conditions in the soil favorable to the activities of those organisms that reduce the organic matter to forms available for plant nutrition with as little waste or loss as possible.

CONDITIONS FAVORING NITRIFICATION.

The processes that result in the decomposition of organic matter in the soil and in the formation of nitrates are favored by a moderate supply of oxygen, the presence of capillary moisture, fairly high soil temperatures, and the presence of free bases to combine with the nitric acid formed. Such conditions are very well provided by the method of tillage used in growing wheat in the Great Basin, as previously described. With that tillage system a large amount of wheat straw with its partially decayed leaves is turned into the soil in the early autumn. The winter rains penetrate the loosened soil, and the continued surface cultivation during the following summer largely prevents the loss of this moisture by evaporation. This surface cultivation also promotes the aeration of the soil, which is essential to the most rapid nitrification, while the absence of plant growth to shade the soil gives the high temperature needed.

The beneficial effects on nitrification processes of the conditions produced by summer fallowing are discussed at some length by Hall[a] in describing the work at Rothamsted, England, where the rainfall is sufficient to leach the soil of the field under experiment:

> It will be seen that the produce of wheat after fallow is considerably higher than when it is grown continuously—17.1 against 12.7 bushels per acre: but if

---

[a] Hall, A. D. The Book of Rothamsted Experiments, pp. 62–66; also pp. 221–223, 1905.

reckoned as produce over the whole area, half in crop and half fallow, the whole acre grows much less both of grain and straw than where the crop is grown year after year on the same land.

An analysis of the results from alternately fallowed plats, however, shows the real benefits of fallowing. Both the seasonal rainfall and the amount of leaching from the land were measured for a series of years, and when the years of light rainfall and consequently diminished leaching are grouped together and contrasted with the years of heavy rainfall and increased leaching, it is seen that the yields following the drier season were high as compared with the others. Thus, for the years when the rainfall for the four months, September to December, inclusive, averaged 8.88 inches and the percolation was only 4 inches, the yield after the fallow was 2,743 pounds, as against 1,810 pounds on the continuous wheat plat, a gain of 933 pounds, or 52 per cent. For the group of years when the rainfall averaged 13.66 inches during the same four months and the percolation was 8.92 inches, the wheat after fallow yielded 1,757 pounds, against 1,627 on the continuous wheat plat, a gain of 130 pounds, or only 8 per cent. In other words, as a result of the decreased percolation more of the nitrates were left in the soil.

It seems probable from these results that with conditions such as exist on the dry lands of the Great Basin, where there is practically no loss by percolation, the products of nitrification during a fallow year would be quite sufficient to overcome any tendency toward the exhaustion of these soils.

THE FIXATION OF NITROGEN.

The bacterial action by which the complex proteids of the organic matter in the soil are converted into nitrates or other forms of nitrogen is but one of the several sources of the nitrate supply of soils. It is well known that bacteria living in the roots of some leguminous plants are able to combine atmospheric nitrogen into available forms, and it has been discovered more recently that practically all cultivated soils contain bacteria which are able to combine atmospheric nitrogen and make it available to plants, drawing their energy meanwhile from the carbohydrate material of the soil humus.[a]

There are many indications that the sustained productiveness of the dry-farmed soils of the Great Basin is due, in part at least, to the activities of this latter group of nitrogen-fixing bacteria. The same conditions that favor the action of the nitrifying or humus-reducing organisms also favor the action of the nitrogen-fixing bacteria, viz, a supply of carbohydrate material as furnished by disintegrating wheat straw, a good supply of soil moisture, high soil temperatures, and the presence of alkaline bases to combine with the nitric acid produced.

---

[a] Hall, A. D. Science, N. S., 22: 453, 1905.

ORGANIC MATTER LOST BY OXIDATION.

In view of the importance of organic matter in maintaining the fertility of these dry-farmed soils there is a strong incentive to avoid excessive losses by direct oxidation.

In maintaining the clean summer fallow previously described, it is necessary to keep the upper 3 inches of the soil thoroughly stirred to form the surface mulch. This portion of the soil, being very dry and well aerated, is kept in a condition which is most favorable to "burning out" the organic matter which it contains.[a] The loss of organic matter in this way can not very well be avoided, for an effective surface mulch is necessary to prevent the loss of moisture from the lower soil. It is possible, however, to very greatly reduce the loss due to oxidation by deep plowing, which increases the depth of the surface soil in which the nitrification and nitrogen fixing can take place. These processes go on very slowly, if at all, in the soil below the furrow slice, so that deep plowing is very necessary to the best results in dry farming, not only as a factor in securing and conserving soil moisture but also in promoting the activities of the various organisms that work in the loosened soil and help to make it productive.

DRY FARMING SUPPLEMENTARY TO IRRIGATION.

With a few exceptions, the irrigated sections of the Great Basin are surrounded by arable lands which are either too high to be economically irrigated or too extensive to be irrigated with the available water supply. In the great majority of cases these lands receive rainfall enough for the production of some special crops even when it is insufficient to support farm homes or even for the growth of wheat and alfalfa with the best of tillage.

It is very doubtful whether a settler would be safe in attempting to make a home and start a farm on even the more promising of these dry lands. At the present time almost all the farming on the dry lands is done in connection with some irrigation farming. In many cases the farmer has little more than his garden and orchard under ditch, but it is at least enough to insure him fruits and vegetables for his table, and, if need be, a little forage for his stock in the event of a severe and protracted drought.

This plan of utilizing the unirrigable dry lands is much safer for the individual and is also much better for the community. Farming with irrigation usually costs more per acre than dry farming, so that wherever it is possible to grow the cheaper staple crops without irrigation it pays to make the attempt. The products of the irrigated land, such as vegetables, fruits, and the succulent forage crops, then find a larger local market, because they can not be produced without irrigation, while live stock and some grain crops can often be produced much more cheaply on the dry lands. Thus the two portions of a community can supplement each other to the profit of both.

---

[a] Storer, F. H. Agriculture, 2: 28-29, 1902.

One of the most important effects of the development of dry farming adjacent to an irrigation settlement is the much-needed lesson it teaches of the value of tillage. Overirrigation with little or no tillage is the most common and serious failing of the western farmer. It is only where irrigation water is costly or can not be had at any price and when crops actually begin to fail that cultivation is seriously resorted to. As a result, it is only in those sections where irrigation is very new or where water is very scarce that the serious effects of overirrigation are not felt. Once the habit is formed, it is much easier to irrigate than to cultivate when a crop shows signs of distress. The ground is therefore filled with water, low places are swamped or made too alkaline for crops, and the fertility of the land is seriously impaired.

With the development of dry farming, however, the beneficial effects of tillage in conserving moisture and in increasing soil fertility give a constant and striking object lesson. When it becomes apparent that many of the same crops can be grown with adequate cultivation and without irrigation as successfully as they can be grown with irrigation alone, a farmer hesitates before undertaking to share the burden of expensive extensions to existing irrigation works. When the extension of a cultivated area is demanded, it becomes at once a practical question whether increased cultivation or increased construction shall be the basis of such extension. Wherever cultivation is resorted to in connection with irrigation the benefits are at once apparent, but without some continued object lesson or some real need, such as scarcity of irrigation water, it is seldom seriously undertaken.

MAKING A HOME ON THE DRY LANDS.

In any situation where dry farming is possible in connection with even a small amount of irrigation, there is much less risk involved than where there are no such opportunities. In fact, in any place where the rainfall is so light as to require extraordinary tillage methods in the production of ordinary crops there is considerable risk in establishing a home without the possibility of using irrigation for at least the farm garden. In nearly every semiarid region the variation in rainfall from year to year is very great, so that one must expect to experience occasional or even frequent dry years, when even with the best of care the ordinary garden crops would fail, and there might even be a shortage of forage for the stock.

It is therefore highly important in selecting a farm on the dry lands to secure provision for some irrigation, at least for the garden. The larger part of the dry lands of the western United States have underground water within reach. Some of them, indeed, overlie artesian basins, so that deep wells supply an abundance of water. In other cases water can be had by lifting, and with windmills or small engines it is considered quite feasible to lift water 200 feet or more for domestic uses and for garden irrigation.

A garden of some kind is almost a necessity for a farm home on the dry lands, as elsewhere, and the means and methods of providing it should be among the first considerations of a new settler.

It is sometimes possible to maintain a garden by taking advantage of the surface run-off after torrential rains, which may be collected by intercepting ditches and run into broad, shallow trenches in the garden until it settles into the ground. A view of a garden in which this method is used is shown in Plate IV, figure 2.

Where ground water lies very deep the expense of reaching it is often too great to be borne by a farmer individually, especially by a new settler, and it is then necessary to attempt a solution of the problem on a community basis. There are vast areas of land in the western United States with enough rainfall for dry farming, yet without any easily available supply of ground water even for domestic use. In some such regions it is often possible to collect rain water from buildings and store enough in cisterns for culinary purposes, but this is sometimes out of the question for a new settler in a treeless country, where building material is scarce and high priced and where he must be content to live for the first few years in a tent house or a small shack. In such situations the water problem must be solved by a community action.

In some instances the extension of dry farming around irrigated centers is limited only by the distance which farmers can afford to haul water to supply the horses or engines required for the farm work. In other cases large tracts of land that are well suited to dry farming are remaining undeveloped because of the absence of springs and the uncertainty as to the presence of an underground supply of water within reach and, if found, as to the proper location of wells.

One of the most urgent needs for the further development of dry farming in the Great Basin is a hydrographic survey for the purpose of determining the location and extent of the underground water resources. Without the information that such a survey might furnish, settlers must either remain in immediate contact with an existing water supply or waste much money that they can ill afford to lose in blind attempts to locate water for themselves.

SUMMARY.

Dry farming in the Great Basin is limited at present almost entirely to the State of Utah, where it has been carried on to some extent since 1875 and its practice has been increasing rapidly since 1900. The work was initiated by private experiments, but the State of Utah is now supporting six experiment farms for testing varieties and working out scientifically the best rotation and tillage methods.

The precipitation comes during the autumn, winter, and spring months, differing in this respect from the precipitation on the dry lands east of the Rocky Mountains, where it comes during the summer months. Farming is successfully carried on with an annual average rainfall of 15 inches or slightly less. The annual variation in rainfall is considerable and the year 1906 was unusually wet. Local topography has a marked effect on the amount of rainfall.

Clean summer fallowing and alternate-year cropping, together with thorough tillage, are the basis of successful dry farming in the Great Basin.

Wheat and alfalfa are the most important crops now grown on the dry lands of the Great Basin. Thin seeding is found essential to the best results with these crops.

Under the best methods of tillage the land appears to remain highly productive even where no other crop than wheat is grown.

Dry farming is now used only as a supplement to irrigation farming. There have been few attempts to make homes on the dry lands.

The independent extension of farming on the dry lands depends upon the development of underground water for domestic use.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Fig. 1.—A general view of the San Juan County Arid Farm, a 40-acre farm maintained by the State of Utah for experimental purposes, located at Verdure, near the town of Monticello. This is one of six farms maintained by the State for similar purposes. The vegetation in the foreground is chiefly black sage, while the trees are juniper. Fig. 2.—A field of wheat in shock on land adjacent to the San Juan County Arid Farm. This field was covered with black sage two years ago.

Plate II. Fig. 1.—Field showing the type of summer fallow maintained in every other series on the San Juan County Arid Farm. This serves at once to kill out weeds, conserve moisture, and promote humification in the soil. Fig. 2.—The interior of an alfalfa plat on the San Juan County Arid Farm. This alfalfa had been cut once and the plants in the interior of the plat made no second growth, while those along the margin next to the well-cultivated roadway were ready for a second cutting at the time shown in this illustration.

Plate III. Fig. 1.—A poor crop of wheat on the Sevier County Arid Farm, Utah. The failure of this crop was apparently due chiefly to a lack of proper tillage during the previous season. Fig. 2.—A crop of wheat grown without irrigation in the Cache Valley, Utah. This land has been producing a crop of wheat every other year for thirty-five years. (Photographed by Mr. Charles J. Brand, 1906.)

Plate IV. Fig. 1.—Harvesting wheat grown without irrigation near Nephi, Utah. A header like that shown will harvest about 25 acres a day. (Photographed by Mr. Charles J. Brand, 1906.) Fig. 2.—A hillside garden in a semiarid region, showing one of the settling ditches used to catch and hold the water which runs off the hill above.

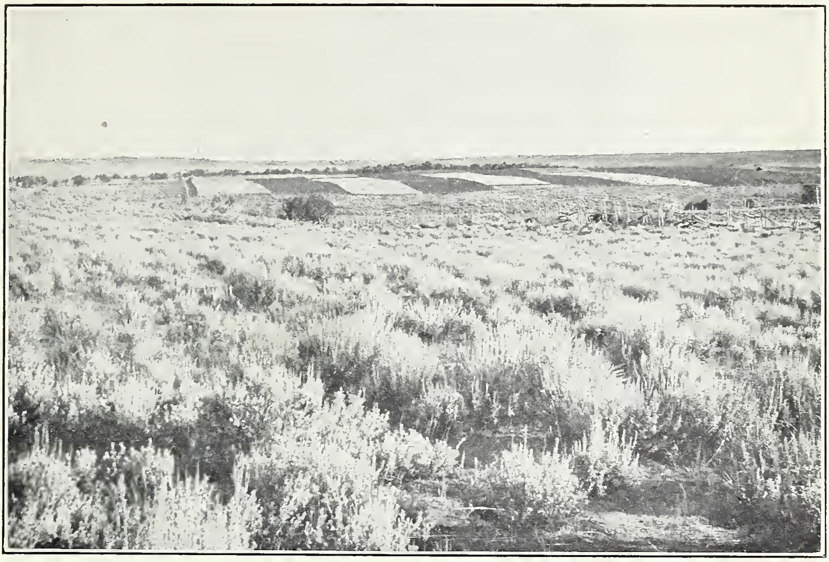

FIG. 1.—GENERAL VIEW OF THE SAN JUAN COUNTY ARID FARM, UTAH.

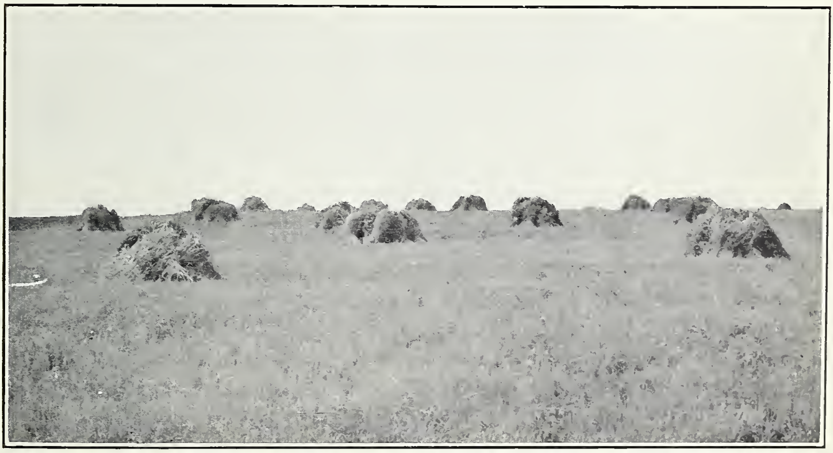

FIG. 2.—FIELD OF WHEAT IN SHOCK ON LAND ADJACENT TO THE SAN JUAN COUNTY ARID FARM.

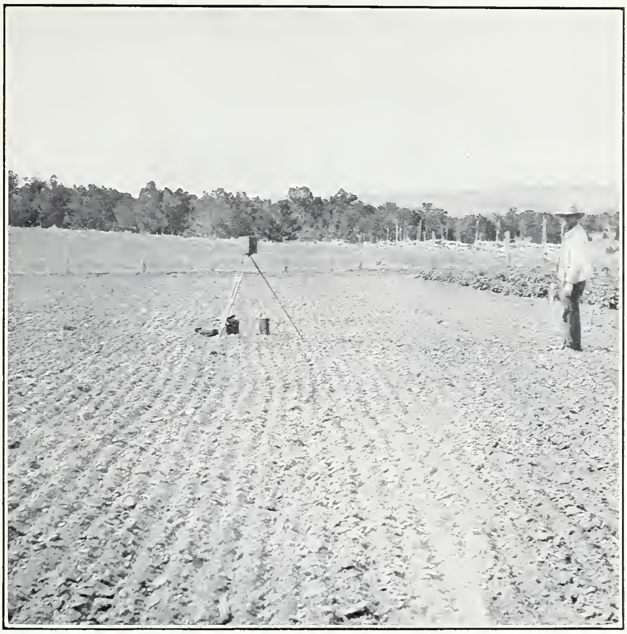

FIG. 1.—FIELD SHOWING THE TYPE OF SUMMER FALLOW MAINTAINED IN EVERY OTHER SERIES ON THE SAN JUAN COUNTY ARID FARM.

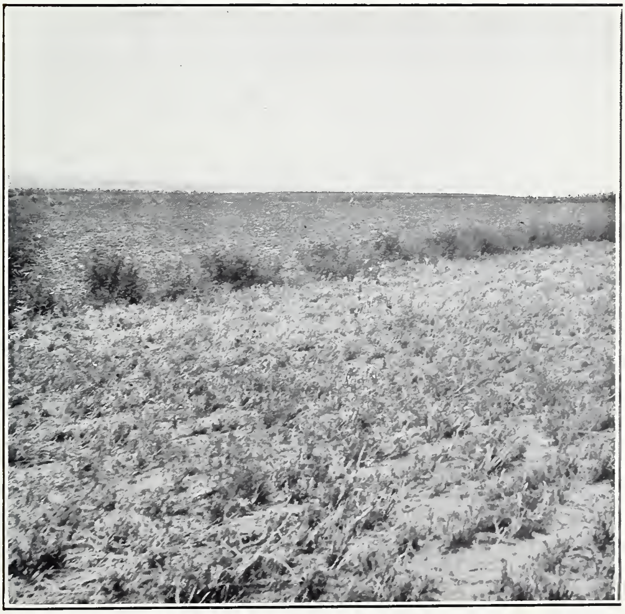

FIG. 2.—THE INTERIOR OF AN ALFALFA PLAT ON THE SAN JUAN COUNTY ARID FARM.

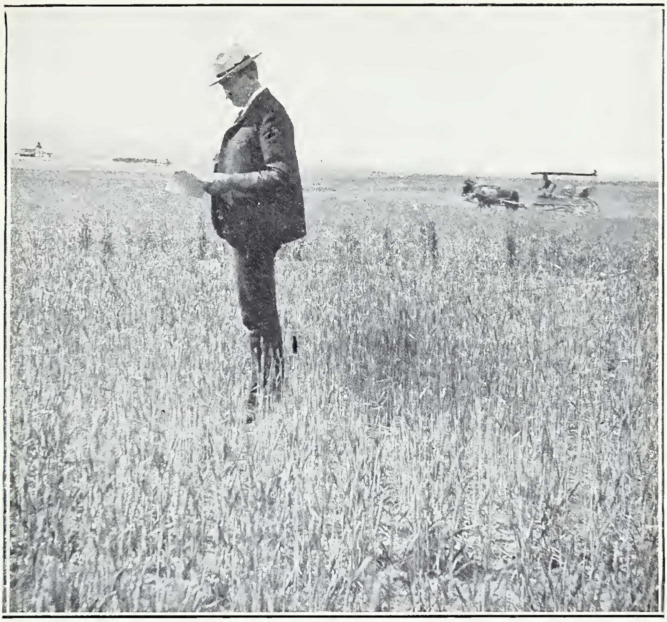

FIG. 1.—A POOR CROP OF WHEAT ON THE SEVIER COUNTY ARID FARM, UTAH.

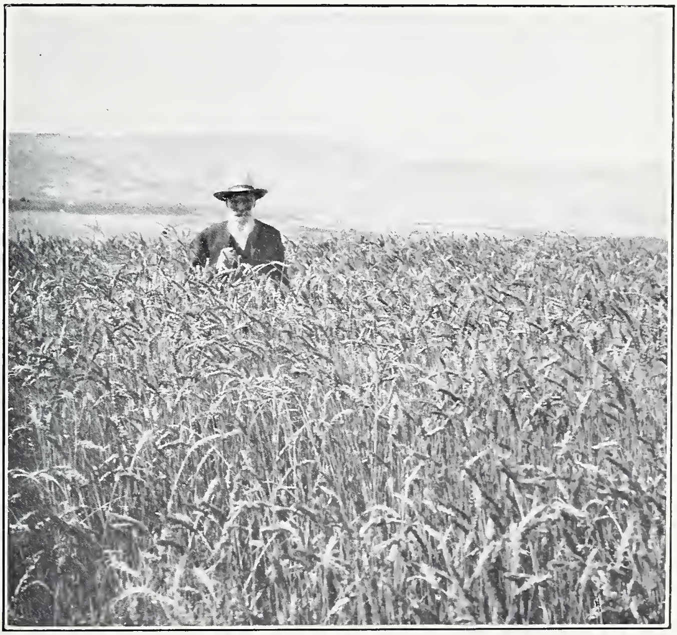

FIG. 2.—A CROP OF WHEAT GROWN WITHOUT IRRIGATION IN THE CACHE VALLEY, UTAH.

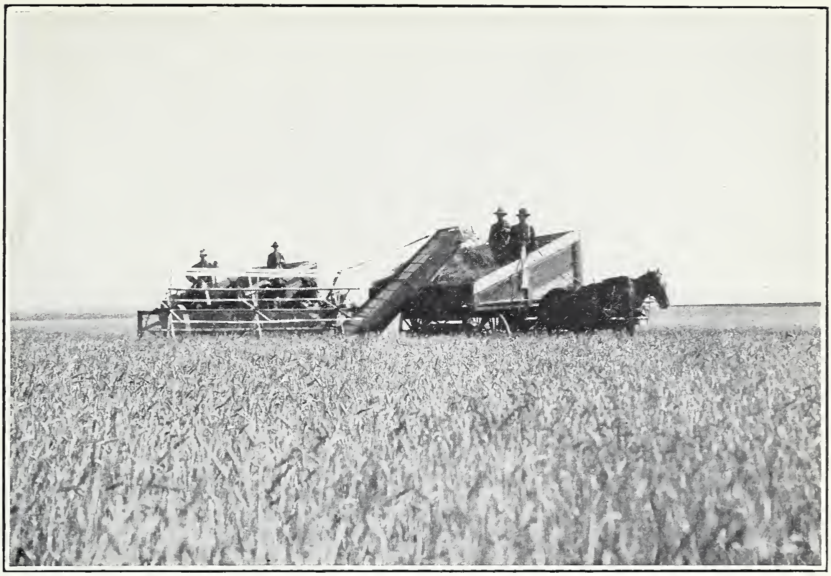

FIG. 1.—HARVESTING WHEAT GROWN WITHOUT IRRIGATION NEAR NEPHI, UTAH.

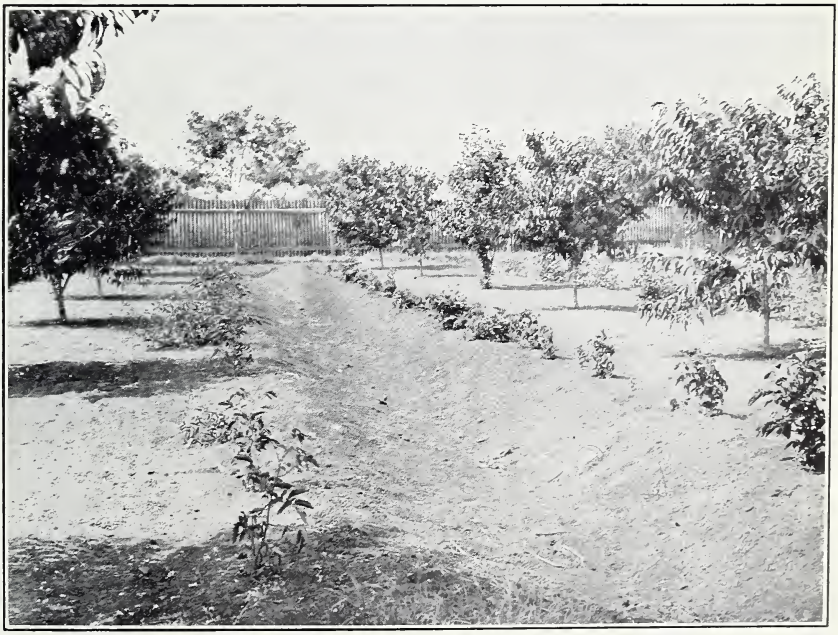

FIG. 2.—A HILLSIDE GARDEN IN A SEMIARID REGION, SHOWING ONE OF THE SETTLING DITCHES USED TO CATCH AND HOLD THE WATER WHICH RUNS OFF THE HILL ABOVE.

INDEX.

Page.
Africa, North, alfalfa cultivation 29
Alfalfa area, Utah, 1899 11
  cultivation, North Africa 29
  drought-resistant varieties, necessity of breeding 27
  planting in rows for intertilled crop 30
  seed production 29
    quantity to acre, humid and semiarid regions 30–31
  tillage in dry farming 29–30
Arid lands, booms, notes 8
  Utah, experiment farms 14
Artemisia tridentata, occurrence, Great Basin area 10
Bacteria, soil, nitrogen-fixing 32, 34
Bear River Valley, dry farming 13
Cache Valley, Utah, private experiments in dry farming 13
Cedars, occurrence, Great Basin area 11
Chrysothamnus, occurrence, Great Basin area 10
Corn area, Utah, 1899 11
Cottonwoods, occurrence, Great Basin area 11
Covillea tridentata, occurrence, Great Basin area 11
Creosote bush, occurrence, Great Basin area 11
Crop areas, Utah, 1899 11
  production, necessity of organic matter in soil 33
  rotation, necessity of intertilled crops in dry farming 12, 17
Crops, dry farming 27–31
  intertilled, advantages for preserving soil moisture 12, 17
Deseret, Utah, precipitation, comparison 21, 23
Disk plow, use in dry farming 23
Dry farming, beginning 8
  development, conditions promotive 7–9
  experiments, Great Basin 11–15
  local conditions 15–21
  pioneer attempts 8–13
  regions, three principal, west of Rocky Mountains 9
  supplementary to irrigation 35–36
Dry lands, home making 36–38
Durum wheats, experiments in dry farming 27
Dust mulch, usefulness in dry farming 25
Experiment farms, arid, Utah 14
Experiments, dry farming, in Great Basin 11–15
Fallow, summer, beneficial effects on nitrification 33
  method in dry farming 24
Farms, arid, experiment, Utah 14

Page.
Fertility, soil, maintenance without rotation of crops 31
Fillmore, Utah, precipitation, comparison 21–23
Flora, Great Basin area 10–11
Forage crop area, Utah, 1899 11
Garden irrigation on dry lands 37
Grasses, varieties native to Great Basin area 11
Greasewood, occurrence, Great Basin area 11
Great Basin, dry-farming experiments 11–15
    location and topography 9–11
    rainfall, comparison with Great Plains rainfall 16–18
Harrow, disk, use in dry-farming 23
Harrows, drag and brush, use in dry farming 24
Hay, alfalfa, in dry farming 29
    area, Utah, 1899 11
Home making on the dry lands, risks 36–38
Hydrographic survey, necessity in Great Basin 37
Implements used in dry farming 22–24
Irrigated land, Utah, area 13–14
Irrigation, excessive, evil results 36
    garden, necessity on dry lands 37
Jordan River valley, dry farming 13
Lahontan, Lake, drainage center, note 10
Law, arid experiment farms, Utah 14
Levan, Utah, dry farming and location 19
Logan, Utah, dry farming and location 18, 19
Malade Valley, dry farming, note 13
Moisture, soil, methods of retaining 22–27
    necessity of conservation 12, 15
    relation to soil texture 26
Mulch, dust, to conserve moisture, dry farming 25
Nevada crops, areas, 1899 12
Nitrification, conditions favoring 33
Nitrogen fixation, action of soil bacteria 34
Oregon, Great Basin region, note 12
Oxidation, loss of organic matter from soil, remedy by deep plowing 35
Parowan, Utah, dry farming and location 19
Plowing, deep, necessity in dry farming 35
Plows, kinds used in dry farming 22
Potatoes, area, Utah, 1399 11
Precipitation, monthly average at representative points in semiarid West 17, 18
    winter, advantages 16–18
    See also Rainfall.
Rainfall, annual, Levan, Utah, 1893–1906 .... 19, 21
        Logan, Utah, 1893–1906 19
        Parowan, Utah, 1891–1906 .... 19, 22
        Tooele, Utah, 1897–1906 .... 19, 20
    influence of local topography 20–21
    relation to soil moisture 26
Richfield, Utah, precipitation, comparison 21, 23
Rotation, crop, necessity of intertilled crops in dry farming 12, 17
Sagebrush, implements for removing 24
    occurrence, Great Basin area 10
Sarcobatus vermiculatus, occurrence, Great Basin area 11

Page.
Seed, alfalfa, production 29, 30
    quantity per acre, humid and semiarid regions 30–31
  wheat, quantity per acre, humid and semiarid regions 30–31
Seeding, thin, essential in dry farming 30–31
Semiarid, nonirrigated farm lands, Utah, area 13–14
  West, precipitation at representative points 17
Soil, cubic foot, weight 25
  fertility, maintenance without rotation of crops 31
  moisture, methods of retaining 22–27
    relation to rainfall 26
  texture, relation to water-holding capacity 25
Soils, dry-farmed, sustained productiveness, causes 31–35
  heavy, nonleaching, desirable for dry farming 32
  water-holding capacity 26
Steam outfit for plowing compared with use of animals 23
Straw, wheat, plowing under, effect on soil fertility, notes 31–34
Subsoil plowing, dry farming 23
Summer fallow, method in dry farming 24
Tillage, crop, in dry farming 27–31
  interseason, methods 22–27
  value, lesson of dry farming 36
Tooele, Utah, dry farming and location 19
Topography, Great Basin 10
Traction engine, use in dry farming 22
Triticum æstivum, growing in dry farming 27
  durum, experiments in dry farming 27
Utah, arid experiment farms 14
  crops and dry-farming practices 12
  crops, areas, 1899 11
  dry farming, pioneer attempts 8, 13
  lake region, dry farming 13
  law providing for arid experiment farms 14
  private experiments in dry farming 13
Vegetables, area, Utah, 1899 11
Wasatch Mountains, dry farming 13
Water-holding capacity of soil, relation to soil texture 25
Weeds, growth in volunteer wheat 29
Wheat area, Utah, 1899 11
  cultivation in dry farming 22
  seed, quantity to acre, humid and semiarid regions 30–31
  straw, plowing under, effect on soil fertility, notes 31–34
  tillage, dry farming 28
  varieties, dry farming 27
  volunteer, disadvantages 28
  yield after fallow years 34
Willows, occurrence, Great Basin area 11

O

[Continued from page 2 of cover.]

No. 54. Persian Gulf Dates. 1903. Price, 10 cents.
55. The Dry Rot of Potatoes. 1904. Price, 10 cents.
56. Nomenclature of the Apple. 1905. Price, 30 cents.
57. Methods Used for Controlling Sand-Dunes. 1904. Price, 10 cents.
58. The Vitality and Germination of Seeds. 1904. Price, 10 cents.
59. Pasture, Meadow, and Forage Crops in Nebraska. 1904. Price, 10 cents.
60. A Soft Rot of the Calla Lily. 1904. Price, 10 cents.
61. The Avocado in Florida. 1904. Price, 5 cents.
62. Notes on Egyptian Agriculture. 1904. Price, 10 cents.
63. Investigations of Rusts. 1904. Price, 10 cents.
64. A Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies. 1904. Price, 5 cents.
65. Reclamation of Cape Cod Sand Dunes. 1904. Price, 10 cents.
66. Seeds and Plants Imported. Inventory No. 10. 1905. Price, 20 cents.
67. Range Investigations in Arizona. 1904. Price, 15 cents.
68. North American Species of Agrostis. 1905. Price, 10 cents.
69. American Varieties of Lettuce. 1904. Price, 15 cents.
70. The Commercial Status of Durum Wheat. 1904. Price, 10 cents.
71. Soil Inoculation for Legumes. 1905. Price, 15 cents.
72. Miscellaneous Papers. 1905. Price, 5 cents.
73. The Development of Single-Germ Beet Seed. 1905. Price, 10 cents.
74. Prickly Pear and Other Cacti as Food for Stock. 1905. Price, 5 cents.
75. Range Management in the State of Washington. 1905. Price, 5 cents.
76. Copper as an Algicide and Disinfectant in Water Supplies. 1905. Price, 5 cents.
77. The Avocado, a Salad Fruit from the Tropics. 1905. Price, 5 cents.
78. Improving the Quality of Wheat. 1905. Price, 10 cents.
79. The Variability of Wheat Varieties in Resistance to Toxic Salts. 1905. Price, 5 cents.
80. Agricultural Explorations in Algeria. 1905. Price, 5 cents.
81. Evolution of Cellular Structures. 1905. Price, 5 cents.
82. Grass Lands of the South Alaska Coast. 1905. Price, 10 cents.
83. The Vitality of Buried Seeds. 1905. Price, 5 cents.
84. The Seeds of the Bluegrasses. 1905. Price, 5 cents.
85. The Principles of Mushroom Growing. 1905. Price, 5 cents.
86. Agriculture without Irrigation in the Sahara Desert. 1905. Price, 5 cents.
87. Disease Resistance of Potatoes. 1905. Price, 5 cents.
88. Weevil-Resisting Adaptations of the Cotton Plant. 1906. Price, 10 cents.
89. Wild Medicinal Plants of the United States. 1906. Price, 5 cents.
90. Miscellaneous Papers: I. The Storage and Germination of Wild Rice Seed. II. The Crown-Gall and Hairy-Root Diseases of the Apple Tree. III. Peppermint. IV. The Poisonous Action of Johnson Grass. 1906. Price, 5 cents.
91. Varieties of Tobacco Seed Distributed, etc. 1906. Price, 5 cents.
92. Date Varieties and Date Culture in Tunis. 1906. Price, 25 cents.
93. The Control of Apple Bitter Rot. 1906. Price, 10 cents.
94. Farm Practice with Forage Crops in Western Oregon, etc. 1906. Price, 10 cents.
95. A New Type of Red Clover. 1906. Price, 10 cents.
96. Tobacco Breeding. 1907. Price, 15 cents.
97. Seeds and Plants Imported. Inventory No. 11. 1907. Price, 30 cents.
98. Soy Bean Varieties. [In press.]
99. A Quick Method for the Determination of Moisture in Grain. 1907. Price, 5 cents.
100. Miscellaneous Papers: I. Cranberry Spraying Experiments in 1905. II. The Wrapping of Apple Grafts and Its Relation to the Crown-Gall Disease. III. Garlicky Wheat. IV. Methods of Testing the Burning Quality of Cigar Tobacco. V. The Drug Known as Pinkroot. VI. Orchard Grass. VII. The Effect of Copper upon Water Bacteria. VIII. Conditions Affecting Legume Inoculation. 1907. Price, 25 cents.
101. [In preparation.]
102. Part I. Summary of Recent Investigations of the Value of Cacti as Stock Food. 1907. Price, 5 cents. Part II. A Successful Dairy Farm. 1907. Price, 5 cents. Part III. Planning a Cropping System. 1907. Price, 5 cents. Part IV. The Application of Vegetative Propagation to Leguminous Forage Plants. 1907. Price, 5 cents. Part V. The Control of Texas Root-Rot of Cotton. 1907. Price, 5 cents.